THE PRICE IS RIGHT: THE IMPACTS OF AGE, QUANTITATIVE KNOWLEDGE, WORKING MEMORY, AND COGNITIVE STRATEGY USE ON MEMORY FOR QUANTITATIVE INFORMATION

by

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ABSTRACT

Research has demonstrated that experts, or those with more knowledge within a particular domain, tend to have better memory for information within that domain. However, there is conflicting evidence as to whether domain knowledge can moderate the relationship between aging and recall. This study tested three models in which knowledge for prices in a grocery shopping domain could moderate the relationship between either age or working memory capacity (WMC), and immediate recall of prices of grocery items. One hundred ninety-eight women memorized and recalled grocery items and their prices divided into realistic and fictitious item categories. Domain knowledge, assessed using a 30-item multiple choice test, was associated with overall recall as was WMC. A small interaction was found in which higher levels of domain knowledge facilitated the recall of realistic over fictitious cue-stem pairs. Supplementary analyses found an association between WMC and overall gist recall. A small interaction was found in which higher levels of WMC facilitated the gist recall of realistic over fictitious cue-stem pairs. Use of more efficient strategies facilitated recall of both types of cue-stem pairs. These results provide support for an over-additive model in which recall is facilitated more for those with higher levels of WMC or domain knowledge. Implications of these findings with relation to the extant body of literature are discussed, including recommendations for future research in this area.

I lovingly dedicate this work to my best friend, Kristi, who has persevered with me through this adventure, and through so many others.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Research into aging and memory has become more salient in the last decade, especially given the large number of individuals who are moving out of middle-age into old age such as the baby-boomers (U.S. Census Bureau, 2011). The impact that age has on memory for quantitative information in every-day domains, such as telephone numbers, personal identification numbers, or activities that involve money (e.g., shopping), has also come under scrutiny for individuals with impaired memory function, particularly with respect to quality of life (Griffith, et al., 2003). Research has determined that a number of important factors contribute to optimal memory: namely, domain knowledge (Hambrick & Engle, 2002), working memory capacity (WMC; Hambrick & Engle, 2002; West & Crook, 1990), age (Lövdén, et al., 2004; Salthouse, 1996; van Hooren, et al., 2007), and the use of cognitive strategies (Baltes & Kliegl, 1992; Dunlosky & Kane, 2007). However, the research on domain knowledge, aging, and long-term memory is contradictory. Some studies have found that domain knowledge mitigates negative changes in memory associated with age (Castel, 2005; Hultsch & Dixon, 1983; Miller, 2003; Morrow, Leirer, Altieri & Fitzsimmons, 1994), while others have found nearly the opposite (Cavallini, Cornoldi & Vecchi, 2009; Hambrick & Engle, 2002). This contradiction in the literature indicates that memory functioning as it relates to domain knowledge is not clearly understood, particularly in everyday domains that are contextually relevant to a rapidly aging population. One such domain involves memory of prices in a shopping environment, as it directly relates to memory for financial information in a context that most individuals will experience throughout their lifetime.

Separately, the use of cognitive strategies (e.g., mnemonics) has been consistently demonstrated to enhance memory for novel information (Verhaeghen, Marcoen, & Goossens, 1992), even among older individuals (Baltes, Sowarka, & Kliegl, 1989; Derwinger, Neely, & Bäckman, 2005; Hill, Allen, & Gregory, 1990). Some of the literature on domain knowledge and expertise has proposed that experts engage some cognitive strategies to assist with memorizing and recalling new information (e.g., chunking; Chase & Simon, 1973). Other studies suggest that experts create elaborate and extensive connections between pieces of information and concepts pertaining to their domain of expertise, and attend to deeper levels of meaning embedded in the information (Bédard & Chi, 1992). Furthermore, experts attend to abstract, rather than surface-level features when solving problems in their domain of expertise (Chi, Feltovich, & Glaser, 1981; Larkin, McDermott, Simon, & Simon, 1980).

The present study proposes to examine the contributions of age, measured domain-specific quantitative knowledge (e.g., knowledge of prices in a shopping environment), and working memory capacity on declarative memory for information within the domain of interest (e.g., prices). The following literature review is divided into four parts: (1) an overview of the scientific literature related to memory and aging, (2) how domain knowledge influences memory, (3) how age and domain knowledge intersect with memory, and (4) the role that cognitive strategies play in memory for new information. Finally, I will describe the present study and develop methods by which to collect and analyze data to test these hypotheses.

Aging and Memory

Quite a few theories exist that describe a) how memory functions over both short and longer periods of time, and b) how aging impacts memory. The following literature review describes working memory and how it interfaces with longer-term declarative memory, and how research has observed these memory systems to degrade over the lifespan. Several theories are then presented that describe how aging could impact declarative memory because of decreases in cognitive resources and impairments in the speed, effectiveness, and economical use of the resources that remain for an aging individual. Neurological and physiological evidence is presented in support of these theories.

When discussing long-term memory, it is almost impossible to not mention working memory because the two are intimately linked. Indeed, working memory and long-term memory share a substantial amount of variance, though each has enough unique variance to be conceptually distinct (Unsworth, 2010; Unsworth, et al., 2009). Working memory has been conceptualized as one's ability to store, manipulate, and process active information over short periods of time (Baddeley, 2000; Baddeley & Hitch, 1974; Engle, Tuholski, Laughlin, & Conway, 1999). This conceptualization of an active short-term memory store differs from previous conceptualizations of short-term memory (Atkinson & Shifrin, 1968), in that it emphasizes the active components of manipulation and processing, whereas traditional descriptions of short-term memory involved passive storage. Baddeley and Hitch (1974) envisioned working memory as having three distinct components: a phonological loop, a visuo-spatial sketchpad, and a central executive. The phonological loop is responsible for actively storing speech-based information, while the visuo-spatial sketchpad actively stores visual information. The central executive works in conjunction with the other two components, and is conceptualized as a switchboard or router between the two sensory stores, processing information from the different stores, and either moving it into long-term storage, manipulating it further, or letting it decay and be forgotten.

The amount of information that can be stored at any time in working memory is described as working memory capacity (WMC). Miller (1956) postulated that the average person's working memory could hold 7 (plus or minus 2) items of information. A more recent and thorough review of the empirical literature on the capacity limits of working memory by Cowan indicates, however, that a more accurate average capacity is 4 (plus or minus 1) items (2001). These items can be singular pieces of information (e.g., a digit), or "chunks" of information (e.g., series of digits that have some inherent meaning, such as a telephone prefix: 801). The assessment of working memory usually involves measuring WMC through span tasks that also address the individual's ability to manipulate the information in working memory (e.g., WAIS-IV digit-span backward or digit-span sequencing).

Baddeley later described a fourth component to the working memory model, the episodic buffer, which acts as a temporary storage area between working memory and long-term memory (2000). The episodic buffer is not only involved in moving information from working memory into long-term memory, but also accessing information in long-term memory that can then be manipulated by the central executive (Baddeley, 2000). The process of moving information from working memory into long-term memory is effortful; that is, it requires active processing of the new information such that the information becomes permanent. This processing can be accomplished through simple repetition, or by somehow associating the information in working memory with the crystallized information in long-term memory (Baddeley, 2010).

Because working memory acts as a gateway to long-term memory, many studies have examined the relationships between these two memory systems, with some studies finding that an individual's WMC substantially predicts later recall. For instance, Park and colleagues (1996) found that WMC accounted for 44% of the variance in long-term memory. They developed a structural equation model that shows WMC and speed of working memory both influencing long-term memory. Other factor analytic and structural equation studies have developed similar, and convergent, models wherein both WMC and long-term memory share significant variance, but are considered independent constructs due to sufficient unique variance (Unsworth, 2010; Unsworth, et al., 2009).

With respect to working memory, deteriorations occur across the lifespan, starting in early adulthood; however, cross-sectional and longitudinal studies disagree somewhat on these findings. For instance, longitudinal studies point to deteriorations occurring after the age of 60, while cross-sectional and cross-sequential studies suggest earlier ages of onset of deterioration (Hedden & Gabrieli, 2004). Regardless of the age of onset, what cannot be denied is that as people age, working memory abilities decline. In a meta-analysis of 203 WMC studies, Bopp and Verhaeghen (2005) found reliable differences between younger and older adults across all the methods of assessing working memory. The most notable differences were on a backwards-span task, which is likely to be more taxing on working memory resources than forward span tasks. The findings that younger adults tend to outperform older adults on working memory tasks has been robust across numerous studies (Craik, Anderson, Kerr, & Li, 1995; Foos & Goolkasian, 2010; Hedden & Gabrieli, 2004; Hester, Kinsella, & Ong, 2004; Salthouse, 1994; Schneider-Garces, et al., 2009), with some studies noting slowed processing speed as one component of the differences between groups (Caplan, DeDe, Waters, Michaud & Tripodis, 2011; Obererauer, Wendland, & Kliegl, 2003). Indeed, one study found that speed of working memory accounted for nearly all age-related variance in memory performance (Park, et al., 1996).

As mentioned, transferring information from working memory into declarative long-term memory is an effortful process. Long-term memory has been conceptually subdivided into that which can be consciously recalled, or *declarative* memory, and that which is often unconsciously recalled such as one's ability to ride a bicycle, or *procedural* memory (Tulving, 1972). Declarative memory has also been conceptually bifurcated: an episodic component for time-limited, experienced or lived events not subject to semantic processes, (Tulving, 1972); and a semantic component for information that has been over-learned (Hermann, 1982). Observable deteriorations in components of declarative memory function begin in middle-age (Salthouse, 1996; 2009) and become more prominent in later life (Lövdén, et al., 2004; van Hooren, et al., 2007). This observation is most notable with episodic memory, and has been observed using numeric (Castel, 2005; Castel, 2007; MacDonald, Stingsdotter-Neely, Derwinger, & Bäckman, 2005;

Raanaas, Nordby, & Magnussen, 2002) and verbal (Luo, Hendricks, & Craik, 2007; Mather & Johnson, 2003; Spencer & Raz, 1995) stimulus material. However, depending on the type of memory task examined (e.g., tasks involving procedural memory), some studies have demonstrated little or no age-related performance differences (Craik & Jennings, 1992). Also, differences between younger and older adults are not as evident when the memory task involves semantic information (Baltes, 1993). These findings indicate that semantic information may be permanent or "crystallized" when compared to episodic memory, which (along with working memory) can be conceptualized as "fluid" (Baltes, 1993), and that age has less impact on the crystallized features of memory than the fluid aspects. These results have been observed in cross-sectional (Baltes & Kliegl, 1992) as well as longitudinal studies (Salthouse, 2011).

Several reasons for deficits in working memory and declarative memory as a function of age have been proposed. Foremost among these are disease processes that occur primarily in old age, such as dementia (National Institute of Aging, 2011). These diseases are often associated with physiological changes in the brain such as neurofibrillary tangles and beta-amyloid plaques (Takashi, et al., 2010); in this respect, memory changes are suspected to occur due to these physiological changes, though the evidence for this description is not always conclusive in that some individuals display these physiological changes without the development of disease processes or memory dysfunction (Riley, Snowdon, & Markesbery, 2002).

Craik and Jennings (1992), in a review of cognitive aging literature, indicated that differences observed between younger and older adults are due in part to limitations in both storage and processing resources; that is, older adults have fewer resources available to allocate to the efficient and accurate processing and long-term storage of novel information. A separate, but similar theory proposes the concept of *attentional resources* (Craik, 1977; Craik, 1986; Craik & Byrd, 1982). This proposition posits that one has finite cognitive resources available that are used for attending to encoding and retrieval tasks: as people age, memory declines are explained by a corresponding decrease in attentional resources.

Another proposition is that as people age, the speed with which they are able to perform cognitive tasks slows down. Salthouse (1996) termed this observed phenomenon *general slowing* as it occurs across all cognitive operations (e.g., reasoning, visuo-spatial abilities, etc.). However, declarative memory is impacted by general slowing because of constraints placed on working memory; that is, the amount of time a memory trace remains in working memory decreases with age, and the processing of information in working memory also slows down (Bailey, Dunlosky & Hertzog, 2009; Salthouse, 1994).

Research involving neuroscience models provides some additional information with respect to theories involving general slowing, or reductions in cognitive resources. Lesions in mylenated connections between neurons in the brain (white matter) are associated with advanced age as well as with decreased cognitive functionality (Salthouse, 2011). It may be the case that these white-matter lesions are responsible for observed general slowing, or for proposed reductions in cognitive resources and processing. Reductions in processing and speed are noted in disease-free aging (Scahill, et al., 2003), though they are especially notable when disease processes that impact memory, such as dementia, are present (Fotenos, et al., 2005); thus, these findings offer a tantalizing explanation for reductions in processing speed, WMC, and reduced efficiency in memory function.

Other research within the realm of neuroanatomy suggests that hippocampal and medial-temporal lobe function is implicit in the formation and recall of memories (Moscovitch, Nadel, Winocur, Gilboa, & Rosenbaum, 2006). One theory posits that when a memory trace is recalled it is immediately re-encoded as a new memory trace, thus leading to the name Multiple Trace Theory. Deficiencies in hippocampal or medial-temporal function could thus result in incorrect recall, leading to an incorrect re-encoding of the original information. Normal or diseased aging processes that impact these areas of the brain (e.g., dementia) could then ostensibly result in degradations of previously consolidated and correctly encoded memories (Moscovitch, Nadel, Winocur, Gilboa, & Rosenbaum, 2006).

Craik and Jennings (1992) indicate that studies point to reduced processing capacity in older adults and suggest that younger adults tend to engage in deeper levels of processing of material, thereby strengthening the recallability of such to-be-remembered information. Baltes (1993) suggests that deficiencies in information processing, like elaborative strategy use or the lack thereof, result in differences in episodic memory performance among older adults. Indeed, some theorize that differences in working memory among older and younger individuals are due to a deficit in the use of cognitive strategies (Bailey, Dunlosky, & Hertzog, 2009). Baltes (1993) indicates that cultural knowledge (semantic information) can be used to bootstrap deficiencies in episodic memory; employing a commonly used study skill technique (i.e. categorization) learned as part of one's formal schooling can act as such a bootstrap (Hill, Storandt, & Simeone, 1990). This bootstrapping effect often occurs when individuals with more knowledge are able to relate this corpus of information to the to-be-remembered information, or when techniques are used to purposefully assist with memory tasks (Bors & MacLeod, 1996). A similar effect is seen with respect to working memory, in that individuals who chunk information into working memory, rather than storing individual items, are able to effectively store more information. Moving chunked information from working memory into long-term memory is also more efficient as it has already been semantically encoded (Cowan, 2001; Unsworth & Spillers, 2010)

Craik and Jennings also note that free recall tasks are more difficult for older adults to negotiate than recognition tasks (1992). This observed difference may be due to cues associated with retrieval, which are present during recognition but not during free recall. To be sure, free recall is a more effortful process and therefore more taxing on cognitive resources, which results in poorer performance. Castel, Farb, and Craik (2007) have postulated that older adults often try for "gist" recall (e.g., a range rather than specifics) during cued recall tasks, whereas younger adults are more likely to attempt recall of specifics during recall. They posit that older adults prefer gist-based memory due to a tacit awareness of deficits in recall precision, or as a type of aging-compensatory strategy for choosing the option that has a greater probability of being successful.

Taken together, these explanations suggest that increases in age can result in decreased cognitive resources and impairments in the speed, effectiveness, and economical use of what resources remain. These deficits could be physiologically grounded, resulting from white-matter lesions that occur as part of normal aging or from disease processes (e.g., a dementia) that also result in neuroanatomical changes. Deficits in memory could also results from the lack of elaborative processing, or other cognitive strategies that could otherwise enhance memory for novel information.

Expertise, Domain Knowledge, and Memory

Expertise within the purview of cognition and memory typically refers to a naturally occurring phenomenon whereby extensive practice or experience within a domain results in improved knowledge for information within that domain (Bors & MacLeod, 1996; Hambrick, 2005). Some studies have used domain knowledge as a proxy for expertise (Hambrick & Engle, 2002; Weber & Brewer, 2003) while others have used time spent in a professional setting (Castel, 2007; Salthouse, 1984). Under some conditions, identifying experts is relatively easy, such as with chess masters whose game rankings can act as an index for expertise; in other situations, identifying experts becomes more difficult, such as measuring the amount of domain knowledge an individual has. One finding that is consistent across all studies of expertise is that experts have more knowledge within their domain of expertise than do novices (Bors & MacLeod, 1996); indeed, many studies have moved past examining expertise per se, and instead focused on how much domain knowledge individuals have (Castel, 2005; Hambrick, 2005; Hambrick & Engle, 2002; Hambrick & Oswald, 2005; Hess & Slaughter, 1990; Jeong & Kim, 2009; Miller, 2003). Thus, domain knowledge appears to offer a tantalizing avenue by which expertise can be studied, and likely provides a better operational definition of expertise than would years of experience, for instance.

Some studies have focused on how individuals with more domain knowledge outperform others on tasks within that domain (Salthouse, 1984), while other studies have focused on how higher amounts of domain knowledge enhance people's ability to memorize and recall information. Memory for chess positions is one of the more commonly examined areas with respect to domain knowledge (Charness, Tuffiash, Krampe, Reingold, & Vasyokova, 2005; Chase & Simon, 1973; Gobet & Clarkson, 2004; Gobet & Simon, 1996; Gobet & Simon, 1998; Guillermo & Gobet, 2005). In particular, Chase and Simon (1973) examined chess experts and described a series of information chunking techniques used by these experts to encode and subsequently recall complex combinations of chess piece positions. Related research (Gobet & Simon, 1996) has suggested that chess experts' chunking strategies contain the locations for more moves as well as the tracking of chess pieces than do novices', and the speed at which experts are able to engage using this chunking method advantages them considerably over novices.

Domain knowledge has also been found to promote memory for baseball (Hambrick & Engle, 2002) and hockey facts (Weber & Brewer, 2003), Scrabble (Halpern & Wai, 2007; Tuffiash, Roring, & Ericsson, 2007), and memory for textual information (Jeong & Kim, 2009; Miller, 2003). In addition, mental representations of music have been examined in musicians (Kalakoski, 2007; Meinz, 2001), as has pilot communication and memory for routes among air-traffic controllers (Morrow, Menard, Stine-Morrow, Teller, & Bryant, 2001; Nunes & Kramer, 2009). One question raised by this research is how does domain knowledge enhance memory for domain-specific information? Most answers to this question involve, to a greater or lesser degree, the crystallized body of knowledge one has within the domain of expertise (Bors & MacLeoud, 1996).

Ericsson and Kintsch (1995) have proposed that experts are able to utilize portions of long-term memory (LTM) much as they might use working memory; that is, experts are able to quickly and efficiently store and retrieve information from LTM, yet the information in LTM is not time limited as it is in working memory. In this way, experts appear to have greater working memory capacities, in that they enlist LTM to temporarily act as working memory. Because of this seeming conjunction of working and long-term memory, Ericsson and Kintsch have termed this phenomenon long-term working memory (LTWM). They further propose that experts are able to perform this feat by using an extensive base of semantic information from their domain of expertise, which they then can use as retrieval cues during memory tasks. Of note, and consistent with the previously mentioned literature on domain-specific memory tasks and expert knowledge, LTWM is only available during encoding or recall tasks within the purview of the domain of expertise. This is to say that, when dealing with information outside the domain of expertise, LTWM is not available. Several studies have tested this theory, and found results supporting the theory of LTWM (Kellogg, 2001; Kintsch, Patel, & Ericcson, 1999; Postal, 2004; Sohn & Doane, 2003).

Directly related to the concept of LTWM is that extensive domain knowledge reduces the demands placed on working memory, freeing cognitive resources for use with the immediate encoding or retrieval task. For instance, Miller, Cohen, and Wingfield (2006) found that when individuals had preexisting knowledge about a particular topic, working memory demands were reduced during a reading task on that topic. Other studies have conceptualized this phenomenon differently, indicating that domain knowledge somehow allows the individual to use WMC more efficiently, essentially enabling more space in WMC to be used for the current task. For instance, Ricks and Wiley (2009) found across four separate studies that when individuals were made aware of the salience of domain knowledge on memory-span tasks, WMC was effectively increased for those individuals with higher levels of domain knowledge. Hambrick and Oswald (2005) found similar results that may have been a moderating interaction between WMC, type of task, and overall recall, but they were more cautious in their interpretation of the findings because the interaction effect was incredibly small. Instead of reducing demands on WMC, Hambrick and Oswald speculate that the effects of domain knowledge and WMC are additive, rather than interactive. A similar interpretation was made in a separate study by Hambrick and Engle (2002).

A second proposition forwarded by Hess (2005) and others (Castel, 2005; Castel, 2007; Hess & Slaughter, 1990) is that domain knowledge creates a larger network of schema, or collections of knowledge, relating to themes or ideas within the domain of expert knowledge. This allows individuals with domain knowledge to better organize novel information into existing schema, likely using meaningful connections between pieces of information. Individuals without the extensive domain knowledge of experts have a smaller network of schema, or fewer connections between pieces of information in the schema, thus reducing their ability to make new and meaningful connections to the novel information (Hess, 2005).

The premise that domain knowledge enhances episodic memory for novel information within the domain of experience has been demonstrated across numerous studies. Some authors have explained this finding by way of schematic support (Hess, 2005), while others have indicated that working memory is enhanced due to reduced demands (Miller, Cohen, & Wingfield, 2006), an increased capacity in working memory

(Ricks & Wiley, 2009), or the allocation of long-term memory to working-memory tasks (Ericsson & Kintsch, 1995).

Domain Knowledge, Age, and Memory

Given that domain knowledge can advantage individuals on domain-relevant memory tasks, one question that is raised is whether domain knowledge can reduce or eliminate the negative effects that advanced age has on memory. The literature on this particular topic is mixed, with some studies supporting the power that domain knowledge has over age-related memory deficits, while other studies finding results that do not conform to this conceptualization.

There are some instances when domain knowledge seems to enable older adults to perform significantly better on memory tasks than they normally would. One often-cited study, designed by Morrow, Leirer, Altieri, and Fitzsimmons (1994), tested younger and older pilots and nonpilots on a series of aviation related cognitive tasks. For older pilots, higher levels of domain experience facilitated more accurate read-back for heading, altitude, and speed when compared to both younger and older nonpilots. This finding persisted when the information was either visually or verbally presented. In a similar study, Nunes and Kramer (2009) found that, among older air traffic controllers, years of experience facilitated performance on some, but not all, cognitive and memory tasks. They indicated that it was on the most complex tasks that experience appeared to be most facilitative. In the realm of professional GO players, Masunaga and Horn (2001) found that higher levels of experience in GO were associated with better long-term recall of information from GO games. Of note, they found significant age x level of experience moderating interactions for long-term recall and recognition of GO information.

These types of results have also been found in memory for spatial information, but only when the older adults are able to rely on task-relevant knowledge, such as the typicality of the information to be remembered (Hess & Slaughter, 1990). In studies that have not looked specifically for a knowledge x age interaction, some evidence supports the premise that domain knowledge can enhance the memory of older adults for prices (Castel 2005; 2007), or for information about famous actors (Hultsch & Dixon, 1983).

In contrast, many other studies that have looked specifically for knowledge x age moderating effects have not found supporting results. One oft-cited study by Hambrick and Engle (2002) proposed three different models that describe the different ways in which domain knowledge, and WMC and age could all potentially interact: a "compensatory" model in which higher levels of domain knowledge would compensate for advanced age or lower WMC; a "building blocks" model in which age or WMC are fundamental to cognitive tasks and limitations in them cannot be overcome; and a "right-get-richer" model in which young age or higher WMC enhance the facilitative effects that domain knowledge has on memory. To test these models, Hambrick and Engle (2002) measured younger and older adult's knowledge for baseball facts, and then tested their memory for baseball relevant and irrelevant information. While they did find that baseball knowledge improved memory for the baseball relevant information across all age groups, the moderating effect of knowledge on age was not significant. The model with the best fit based on their data was the "rich-get-richer" model, suggesting that higher levels of WMC enhance the positive effects that domain knowledge has.

Nonsignificant results with respect to a knowledge x age interaction have been observed in a number of different studies that examined memory for textual information (Cavallini, Cornoldi, & Vecchi, 2009; Jeong & Kim, 2009), imagery and spatially based information (Arbuckle, Cooney, Milne, & Melchior, 1994; Lindenberger, Kliegl, & Baltes, 1992), music (Meinz, 2001; Meinz & Salthouse, 1998), and air-traffic control information (Morrow, Menard, Stine-Morrow, Teller, & Bryant, 2001). Although nonsignificant moderating results were found, what should be noted across all of the aforementioned studies is that some attenuation of memory deficit was noted; that is, higher mean scores on memory tasks were observed for all individuals with higher levels of domain knowledge compared to persons with lower levels of knowledge.

Some confusion remains about why such different results can be found among studies examining whether domain knowledge can attenuate age related declines in memory. Hambrick and Engle (2002) suggest that the discrepancies between studies can be attributed to, at least in part, methodological limitations. For instance, they indicate that most studies that have found significant impacts of domain knowledge on age-related changes in memory have not accounted for the substantial impacts of WMC. In their own study, one of the primary reasons a knowledge x age moderating effect was not observed was because of the variance already accounted for by WMC in LTM. Another suggestion made by Hambric and Engle (2002) is that further explorations into how domain knowledge interacts with aging and memory are warranted, particularly in domains not yet studied.

Related to Hambrick and Engle's (2002) suggestion for continued study into new domains is another possible explanation for the contradictory findings in domain knowledge studies: most studies deal with very specific domains that are likely not salient to the average older person (e.g., hockey or air-traffic control). Hess (2005) suggests that aging and memory studies must take into account the ecological validity of the memory tasks in which participants are asked to engage. Tasks that do not relate to situations in which older adults can rely upon the knowledge they have gleaned over a lifetime are unlikely to capture a complete picture of memory in aging. For instance, Castel (2005) examined a domain that nearly every person will have experienced at some point in their lives: prices for grocery items. Over two experiments, Castel had older and younger adults memorize prices for commonly occurring grocery items (e.g., butter: $2.99) under conditions where the prices were accurate or inaccurate. He found that when the prices were accurate, the older adults performed just as well as did the younger adults. He interpreted these results to indicate that older adults had, over a lifetime, developed substantial amounts of domain knowledge relating to the typicality of grocery item prices that allowed them to better recall accurately priced items.

In sum, studies examining domain knowledge, aging, and episodic memory present some mixed results: in some instances, domain memory does appear to provide significant improvements in memory for older adults, while in other instances, it does not. It may be that methodological limitations in some studies, such as not accounting for WMC, predispose them to find significant but inaccurate results. Alternatively, the results may have more to do with the domains being studied and whether they represent domain knowledge a typical individual will obtain rather than from an obscure domain that is not salient to a general population.

Cognitive Strategies, Aging, and Memory

Most people learn, over time, that strategies make learning and manipulating new information easier. A literature on self-generated mnemonic skills suggests that individuals can spontaneously learn strategies and become more proficient with learning information over short and long periods of time. This phenomenon is embedded in research that has examined self-generated mnemonics or specialized skills that people learn through natural processes that could be construed as training. These self-generated mnemonics are then employed to facilitate recall of information.

Several studies have examined how cognitive strategy use impacts shorter-term memory and WMC, and have consistently found that strategy use improves WMC. For instance, Bailey, Dunlosky, and Hertzog (2009) found that differential use of strategies accounted for a significant proportion of variance in WMC. Other explorations into the impact of cognitive strategies on WMC have provided comparable results (Dunlosky & Kane, 2007).

Several studies have deliberately examined ways to attenuate differences between young and old adults in free recall through highly strategic cueing systems that involve systematic strategies such as mnemonics (Baltes & Kliegl, 1992; Kliegl, Smith, & Baltes, 1989; Kliegl, Smith, & Baltes, 1990). For example Kliegl, et al. (1990) reported enhanced pre-to-posttest gains in older adults trained in a mnemonic known as the method of loci, or the placing of items in familiar self-generated locations in their imagination. This procedure, once learned, diminished age-related performance deficits to the point where trained older adults performed as well on the task as untrained younger adults (Kliegl, et al., 1990). Other research in older subjects (Luo & Craik, 2008) has demonstrated similar benefits in episodic memory tasks from strategy use.

Formalized training in a mnemonic strategy is not necessary to derive benefits from the use of other cognitive strategies; indeed, individuals can and do develop many strategies on their own. In a study directly related to this issue, Hill, Allen, and Gregory (1990) examined the effectiveness of self-generated mnemonics in word recall tasks for older adults. An analysis of the strategies reported by 111 older adults suggested five categories: repetition, simple association, a descriptive story, grouping or categorizing, and first letter techniques (e.g., alphabetizing). Nearly 45% of the participants indicated they used a mnemonic with some deeper level of processing (story, grouping, and first letter). Deeper levels of processing also led to greater recall at immediate posttest as well as a 2-day posttest. In a later study, Hill, Schwob, and Ottman (1993) examined the effectiveness of self-generated mnemonics for two-digit prices and four-digit phone numbers with younger and older adults. The self-generated strategies that they identified included rehearsal, association with prior knowledge (e.g., birthday), ordering or ranking, grouping, and visualization. The use of strategies benefitted both the younger and older participants in this study, though a greater percentage of younger- and middle-aged adults reported using mnemonics compared to the older adults.

Even simple self-generated strategies, such as repetition or using one's imagination, have been demonstrated to advantage individuals of all ages on memory tasks. For instance, Price, Hertzog, and Dunlosky (2008) found that individuals who are made more tacitly aware of the benefits of using even simple strategies tended to perform better on memory tasks than those who were not. Of note, in their study, they found that imagery produced significantly better recall outcomes than repetition; and that younger adults benefitted more than did older adults. Other studies have also found that younger adults tend to gain more from the use of cognitive strategies than do older adults (Hertzog, Sincliar, & Dunlosky, 2010), but the fact remains that older adults can substantially alter their memory performance in a positive direction when using mnemonics or other strategies.

Derwinger, Neely, and Bäckman (2005) suggest that mnemonic training can have beneficial effects for long-term retention of new material for older adults, and that self-generated strategies may be superior under some conditions than trained strategies. Other studies examining the number-consonant mnemonic in older adult populations have shown that explicit strategy training is effective for long-term retention of numeric information (Hill, Campbell, Foxley, & Lindsay, 1997). Baltes, et al. (1989) suggest similar durability of self-generated strategies for other cognitive tasks beyond numbers.

Although the research performed by Derwinger, et al. (2005) has indicated that self-generated mnemonic strategies have advantages over formal mnemonic training for older adults; the latter has empirical support and its examination allows insight into memory-related deficits among a population not trained in formalized mnemonics. Related research suggests that different types of mnemonic training may have varying levels of effectiveness for older adults. To examine this possibility, Verhaeghen, Marcoen, and Goossens (1992) performed a meta-analytic study on different mnemonics. The mnemonics they examined were method of loci, name-face, peg word, paired associates, and organization. They compiled 31 research papers and 33 studies, with a final sample of 1539 older adults. Their meta-analysis revealed that older adults benefited more from mnemonic training than from either a placebo or a control on measures of treatment gain. Additionally, a direct comparison of mnemonic training to control groups among the studies showed a significant difference favoring the mnemonic training. Their analysis of literature that involved the use of a single mnemonic showed little differences in effect sizes due to type of mnemonic used. This finding suggests that regardless of mnemonic type, some form of memory training can provide benefits for older adults. Their conclusions indicated that memory proficiency can be enhanced in old age and that mnemonics are facilitative of gains in memory performance.

Research has indicated that one way to mitigate age-related declines in memory is to use mnemonics through informal (self-generated strategies) or formal (mnemonic) procedures. Either way, the benefits of memory aids tend to be strongest when individuals become expert in using these procedures. For instance, Kliegl, Smith, Heckhausen, and Baltes (1987) have demonstrated that use of the history-dates, and method of loci mnemonics enables younger adults to obtain digit spans near that of memory experts. Developing strategies that make for efficient information processing as part of one's domain of experience seems as though it would be a natural process; yet few studies have examined if or how experts engage in the use of strategies. Indeed, in all of the studies cited herein, none have directly assessed the cognitive processes experts, or those with higher levels of domain knowledge, go about while learning and recalling new domain information.

The Present Study

Declarative memory, especially episodic, is demonstrably impacted by several factors, including advanced age (Salthouse, 1994), working memory capacity (WMC) (Park, et al., 1996), domain knowledge (Unsworth & Engle, 2005), and the use of cognitive strategies (Bailey, et al., 2007; Dunlosky & Kane, 2007). Investigations into whether domain knowledge can mitigate age-related declines in episodic memory have shown mixed results; that is, some studies show a significant moderating effect of domain knowledge on memory (Masunaga & Horn, 2001), while others have not found the same moderating effect (Cavallini, et al., 2009; Hambrick & Engle, 2002). One possibility for this discrepancy in the literature is that WMC was not accounted for in the studies that did find a moderating effect. Hambrick and Engle (2002) indicate that because WMC contributes substantially to long-term memory, and because WMC is a component of memory negatively impacted by aging (Bopp & Verhaeghen, 2005), future studies should include this substantial contributor when examining long-term memory.

Another possibility is that, in nonsignificant studies, the domains being examined were not especially salient to older adults and therefore did not allow them to rely on a lifetime of acquired domain knowledge. Hess (2005) indicates that for memory and aging studies to be ecologically valid, studying domains that are contextually relevant to older adults is imperative. Indeed, studies that have followed this advice have tended to find that domain knowledge mitigates age-related declines in long-term memory (Castel, 2007; Hess & Slaughter, 1990).

Separately, numerous studies have demonstrated that when older adults use cognitive strategies, they perform significantly better on memory tasks. These findings are robust with respect to formalized mnemonics (Verhaeghen, Marcoen, & Goossens, 1992), as well as with self-generated strategies (Derwinger, et al., 2005); and strategies impact both WMC (Dunlosky & Kane, 2007) as well as declarative memory (Verhaeghen, et al., 1992). Some researchers intimate that age-related memory declines may be due to a lack of sufficient strategy use on the part of the older individual (Bailey, et al., 2009). Domain knowledge may predispose individuals to develop strategies that enable them to form better and more meaningful connections between new information and preexisting domain knowledge (Hess, 2005). However, the exact strategic mechanisms that experts, or individuals with greater levels of domain knowledge, engage in to assist with memorizing and recalling information has not yet been explored.

The primary purpose of this study was to examine which of Hambrick and Engle's (2002) models (compensatory, building blocks, or rich-get-richer) best described the data that were collected. Following Hess's (2005) suggestion, this study examined measured domain-specific quantitative knowledge within a domain that is contextually relevant to a general population: namely, knowledge of prices in a grocery shopping domain. This study also examined the impact that knowledge of prices has on immediate recall for domain specific quantitative memory (e.g., grocery prices). Because previous studies have demonstrated that domain knowledge only has a facilitating effect for domain-congruent information, the grocery items were manipulated such that the names of some were realistic (congruent) whereas the names of others were fictitious (noncongruent). In addition, the present study examined whether said domain knowledge had a moderating effect on the negative influences of age on immediate recall of prices, after accounting for the contributions of WMC, as per Hambrick and Engle's (2002) recommendation. As an exploratory step, individual's use of cognitive strategies was assessed to assist with explaining the relationships among the study-specific variables.

Based on Hambrick and Engle's (2002) work, three possible moderation models are proposed in which domain knowledge can moderate the relationships between either age or WMC, and immediate recall of prices. The first is an under-additive model where higher levels of domain knowledge compensate for advanced age or lower WMC. As seen in Figure 1, domain knowledge can attenuate, or even eliminate, the negative impacts that older age has on recall. Cognitive ability (i.e., WMC) becomes less important as individuals move from minimal amounts of domain knowledge to higher amounts. The next model is an additive model in which domain knowledge cannot overcome the contributions made by WMC or advanced age. In this model, age and WMC are considered fundamental to cognitive functioning, and as can be seen in Figure 1, contribute to recall even at high levels of domain knowledge. The final model is an over-additive model in which the facilitative effect on recall from higher levels of domain knowledge is enhanced by greater WMC or younger age. Figure 1 shows how individuals who are younger or with greater amounts of WMC benefit from more domain knowledge than do those individuals with less WMC or who are older.

Although not hypothesis-driven per se, the present study had several a-priori expectations based on extant theory:

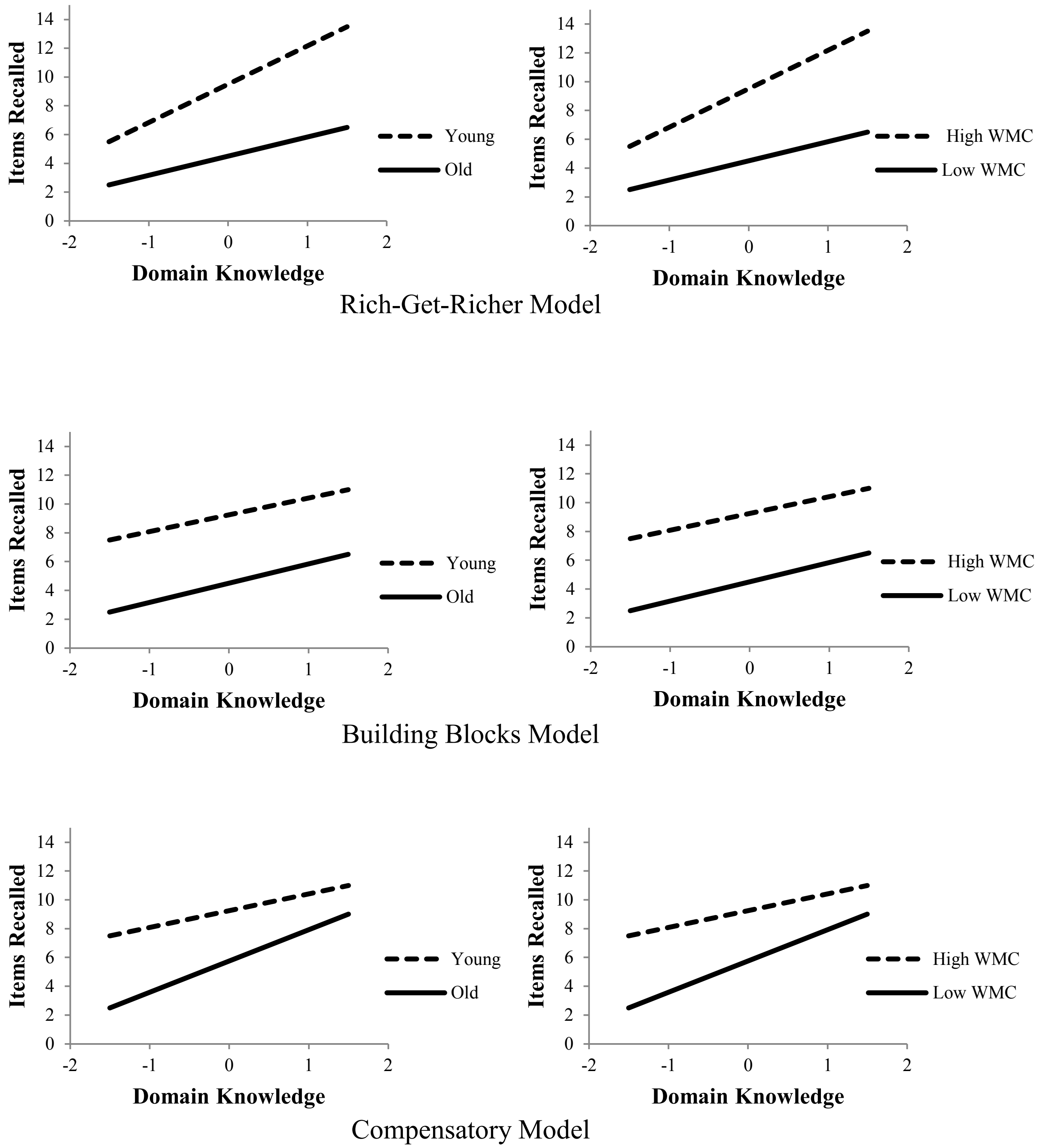

Figure 1: Graphical representations of the possible moderating effect of domain knowledge on age or WMC. Domain knowledge has been mean-centered and is represented as a z-score. Top row: Rich-Get-Richer model. Middle row: Building Blocks model. Bottom row: Compensatory model. Left column: Young versus older adults. Right column: High versus low WMC.

1) Aging would have a negative effect on immediate recall; younger individuals would have better recall than older individuals.

2) Aging would have a negative effect on working memory capacity; younger individuals would have larger working memory capacity than older individuals.

3) Higher levels of domain knowledge would facilitate recall of domain congruent information (realistic items) compared to domain incongruent information (fictitious items).

4) Greater amounts of working memory capacity would facilitate recall of all types of information.

5) The use of cognitive strategies would have a facilitative effect on the recall of information. This effect would be greater for more efficient strategies (e.g., associative elaboration) compared to less efficient strategies (e.g., repetition).

CHAPTER II

METHODS

Ethics Statement

This study adhered as strictly as possible to University of Utah ethical policies, as well as local, state, and national laws relating to human subjects research. The study protocols, design, and recruitment techniques were approved by the University of Utah's Institutional Review Board (IRB # IRB_00056318), and by the State of Utah's Department of Human Services (DHS IRB # 0517). The University of Utah Institutional Review Board reviewed and approved this research on April 12, 2012 (see Appendix A). The Utah Department of Human Services IRB reviewed and approved this research on March 20, 2013 (see Appendix B). Written consent was obtained from all participants immediately prior to their beginning the study. The consent document is presented in Appendix C.

Sampling Methodology

Participants were recruited from a variety of locations throughout the Salt Lake County area: The University of Utah Educational Psychology Subject Pool, The University of Utah OSHER Life Long Learning Institute, the Murray campus of Columbia College, five Salt Lake County senior centers, the 2013 Generation's

Conference, and through print and digital advertisements. Participants were queried about the location from which they had been recruited; however, 125 participants chose not to answer the question. Therefore, frequency data about recruiting efforts from various locations is incomplete.

The sample was restricted to females for several methodological reasons. Because of the number of variables under consideration in this study (age, domain knowledge, WMC, types of items) and the numerous interactions among these variables, one possible concern with this study was insufficient power. Some research evidence suggests that sex provides a small (i.e., 1% to 4% favoring females) but significant contribution to accuracy of recalled information (Heaton, Taylor, & Manly, 2003; Taylor & Heaton, 2001), while others have found larger effect sizes (Herlitz, Nilsson, & Bäckman, 1997; Sunderaman, et al., 2013). Therefore, restricting the sample to women likely improved the power of the employed statistical tests by removing this source of variance, as well as by allowing for one additional degree of freedom in the statistical analysis. Additionally, the University of Utah Educational Psychology subject pool from which a number of participants were recruited was primarily female, and which reflects the larger proportion of females over the age of 50 in the United States (U.S. Census Bureau, 2011). Restricting participants to the female gender increased the homogeneity of the sample, thus increasing statistical conclusion validity.

Because some disease processes (e.g., dementia) can have substantial negative impacts on working memory and immediate recall (National Institute of Aging, 2011), participants were briefly screened prior to participation and asked if they had dementia, or a known medical condition that could cause a substantial memory impairment (e.g., Parkinson’s disease, multiple sclerosis). Participation was restricted to those individuals who did not have a known diagnosis of a disease process that could impair memory.

The University of Utah Educational Psychology Subject Pool is composed of individuals enrolled in one of many Educational Psychology undergraduate courses. Some of these courses include, as part of the student’s grade, the requirement to participate in research being conducted in the Educational Psychology department (or engage in an alternative activity). The instructors for these courses are not affiliated with the present research. Participation in research is a requirement of the student’s course of study, and subjects participate as part of the subject pool for the Department of Educational Psychology, which has independent IRB approval. Students in these courses are typically juniors or seniors in their undergraduate programs, between the ages of 20 and 24 years old, and approximately 80% of the students are female.

The University of Utah OSHER Life Long Learning Institute (OSHER) provides noncredited classes for older adults who wish to continue their education or engage in social activities within an institution of higher education. In-person recruitment was conducted during a class on human memory. In addition, a flyer that described the research and how to contact the researcher was posted in the OSHER building (see Appendix D).

Columbia College is a private educational institution that provides services primarily to working adults. At the Murray, UT, campus of Columbia College, in-person recruitment was conducted before several classes. In addition, a flyer that described the research and how to contact the researcher was posted in a common area (see Appendix D).

Salt Lake County senior centers are social hubs and gathering places where active adults over the age of 60 can explore a multitude of interests. Five senior centers agreed to allow recruitment of their members for this study. In-person recruitment was conducted at the Magna-Kennecott Senior Center and at the Mt. Olympus Senior Center. In addition, a flyer that described the research and how to contact the researcher was posted at the Magna-Kennecott Senior Center, the Mt. Olympus Senior Center, the Draper Senior Center, the Friendly Neighborhood Senior Center, and the Sunday Anderson Westside Senior Center (see Appendix D).

During the 2013 Generations Conference, which was located at the Salt Palace Convention Center in downtown Salt Lake City, a booth that advertised this research was located in a common and highly visible area. Individuals attending the Generations Conference were mental health professionals across a wide range of ages. A sign-up sheet was provided for those individuals who were definitely interested in participating; these people were called or emailed to confirm their participation. In addition, a flyer that described the research and how to contact the researcher was placed prominently at the front of the booth (see Appendix D).

A digital advertisement, detailing the study, the inclusion criteria, and compensation, was posted to multiple online venues (see Appendix E). These included Craigslist.com, KSL.com classifieds, backpage.com, and the online version of the Salt Lake Tribune.

Printed advertisements detailing the study, the inclusion criteria, and compensation, were posted on community boards and at willing businesses throughout the Salt Lake County (see Appendix D). The primary locations included Ream's and

Harmon's grocery stores, and were chosen as they have free, public community boards that are easily visible by their patrons. Several of these locations were also located close to retirement communities or nursing homes, and were expected to promote the research to a wider range of older participants.

Participants

A total of 218 individuals participated in this research. During testing, 1 participant who spoke English as a second language was observed to have substantial difficulty understanding the instructions. Her data were removed from the final analysis and were not included in the description of participant characteristics.

Three participants omitted their age; therefore, their data were replaced with the mean value of the remaining participants. Participant’s ages ranged from 17 to 90, with a mean of 34.94 (*SD* = 19.62). Years of education completed ranged from 9 to 22, with a mean of 15.38 (*SD* = 2.34).

During initial data screening, 20 participants were identified as univariate or multivariate outliers, and the Results section details this data screening process. The data from these 20 participants were excluded from the final analysis. Excluding these 20 participants resulted in a final sample of 198. In this final sample, participant’s ages ranged from 17 to 90 with a mean of 33.15 (*SD* = 17.9). Years of education completed ranged from 9 to 22, with a mean of 15.38 (*SD* = 2.25). These data are also presented in Table 1.

Table 1

Descriptive Statistics

Variable Name	Minimum	Maximum	Mean	*SD*
Age[a]	17	90	33.15	17.9
Years of Education	9	22	15.38	2.23
Domain Knowledge[b]	13	22.5	17.54	1.95
Working Memory Capacity[c]	-2.37	1.74	0.07	0.91
Digit-Span Backwards	2	16	11.3	2.93
Digit-Span Sequencing	1	16	11.17	2.97
Letter-Number Sequencing	12	29	22.75	3.78
Declarative Memory[d]				
Realistic Items	0	11	3.76	2.72
Fictitious Items	0	9	1.92	1.99
Declarative Memory (Distance score)[d,e]	0.30	16.70	7.46	3.46
Realistic Items	2.11	33.07	15.80	5.15
Fictitious Items				

a. Three missing values were replaced with the mean of 33.15
b. Based on a total of 30 items
c. The WMC composite was created using the WMC subscales (DSB, DSS, and LNS) and was transformed into a composite through a first-order principle components extraction creating a mean-centered variable that is interpreted as a z-score.
d. Based on a total of 30 cue-stem pairs: 15 realistic cues and 15 fictitious cues
e. The distance score was calculated as the absolute deviation between the recalled price and the actual price. Higher scores represent poorer overall recall.

Materials

Quantitative domain knowledge

Quantitative domain knowledge of grocery store prices was assessed using a 30-item multiple-choice test designed specifically for this study. Over a 1-week period in March of 2012, 82 common grocery store items (e.g., milk, crackers, soda, etc.) and their prices were sampled from five different grocery stores throughout the Salt Lake valley: Walmart, Target, Reams, Smith's, Harmon's, and A-Fresh Market. These stores were chosen because of the likelihood that they would be frequented by an average individual, whereas bulk stores (e.g., Costco, Winco) were excluded because an average individual might not regularly purchase their groceries from this type of store. Organic or specialty items were also excluded because an average individual might not purchase these items regularly. When multiple types of a grocery item were present (e.g., skim, 1%, 2%, or whole milk), only one type of this item was chosen for inclusion. Only those grocery items that were precisely the same across stores based on weight, size, and brand were considered for inclusion.

Of the 82 grocery items surveyed, 30 were randomly chosen for the domain knowledge test. Thirty items for a domain knowledge test is consistent with other studies that have assessed domain knowledge (e.g., Hambrick & Engle, 2002; Hambrick & Oswald, 2007). Average prices for each item were computed along with standard deviations. The domain test was then designed as a multiple choice test using the average price of the item as the correct answer. The ordinal placement of the correct answer (a., b., c., d., or e) was equalized across questions such that no option was used too frequently. The incorrect options were based on the standard deviation of the price, and ranged from 1 to 4 standard deviations above or below the mean, depending on the placement of the correct answer. Thus, a participant might see the following (where option C, bolded, is the correct answer):

1. Diced Tomatoes (canned, 14.5 oz)
   a. .21
   b. .67
   c. 1.13
   d. 1.58
   e. 2.04

In the above example, options a and b were 1 and 2 standard deviations below the mean, respectively, while options d and e were 1 and 2 standard deviations above the mean, respectively. All 30 items were presented simultaneously on a computer screen, and the participant was given instructions indicating: "For each of the following 30 grocery items, please select which price you think is the one that is most accurate. Which price would you expect to see in a grocery store? When you are finished with all 30 items, please click 'next.'"

The domain knowledge test was pilot tested on 30 individuals. During pilot testing, item variability was non-zero across all items and no problematic items were identified; therefore, no changes were made to this instrument prior to beginning data collection. The final 30-item test is presented in Appendix F.

Several different approaches to scoring the domain knowledge test were used to determine the most reliable scoring methodology. Scoring items as absolutely correct or incorrect, one point per question correct, provided low reliability (Cronbach's alpha = .23). A second method of scoring, wherein one point was given for a correct answer, and half a point was given for an option ±1 standard deviation from the correct score, provided slightly higher, though still low, reliability (Cronbach's alpha = .34). Other methods of scoring (e.g., partial credit of .25 points for ±2 standard deviations from the correct answer, .5 points for ±1standard deviation from the correct answer, and 1 point for the correct answer) provided lower reliability than the initial scoring methodology. Therefore, the final approach to scoring was to award one point for each correct answer, and one half point for each option that was ±1 standard deviation from the correct score; other answers (i.e., ±2 or 3 standard deviation options) were awarded no points. This method of scoring allows for the fluctuation of market prices that may have been represented in this test, yet does not heavily penalize those individuals who may have chosen the incorrect answer because of this market fluctuation. An individual's score for domain knowledge of grocery prices in a shopping environment was computed as the total number of points scored on the test. Higher levels of domain knowledge were associated with higher scores on the test. The total time taken to complete this test was recorded, but not the time taken to answer individual items.

Working memory capacity

Working memory capacity (WMC) was assessed using three different measures derived from the WMC tests from the fourth edition of the Wechsler Adult Intelligence Scales (WAIS-IV, 2008). The first, digit-span backward (DSB), involves the sequential presentation of digits (e.g., 2-7-5), which the individual must then repeat backward (e.g., 5-7-2). The second, digit-span sequencing (DSS), involves the sequential presentation of numbers (e.g., 2-3-1), which the individual must then repeat the numbers in order, starting with the lowest number (e.g., 1-2-3). The third, letter-number sequencing (LNS), involves the presentation of digits and letters (e.g., 2-A-7-Q), which the individual must then sequence alphabetically and then ascending numerically, in that order (e.g., A-Q-2-7).

These span tasks were chosen over other span tasks (e.g., O-Span; Hambrick & Engle, 2002) as they are relatively quick to administer and thereby decreased the amount of time participants engaged in testing. Of note, the WMC tasks in the present study were not copied verbatim from the WAIS-IV, but were based on the WAIS-IV tests with respect to item similarity, item length, timing, and scoring. Like the WAIS-IV WMC tests, the WMC tests in the present study were adaptive in that if a participant correctly answered at least one trial in an item, they progressed to a longer and more difficult item. Unlike the WAIS-IV WMC tests, the present study's WMC tests were visually presented on a computer screen, and the responses were typed rather than given orally. Although the visual presentation of these tests differs from the WAIS-IV protocol, visual presentation of the WAIS-IV WMC tasks has been successfully performed in a research setting (Kemtes & Allen, 2008). In such research, younger adults were able to recall more digits than older adults regardless of modality of presentation (auditory versus visually) and differences were found between auditory and visual presentation of the materials with the auditory presentation resulting in better performance overall. The auditory and visual presentations were strongly related (r = .58), suggesting that both methods of presentation are tapping a similar construct. In addition, some justification exists for visual rather than auditory presentation of the WMC stimuli, as older adults often have hearing problems that are not correctable, whereas vision problems are more easily remediated (Kemtes & Allen, 2008). Given that a number of the participants in the present study were expected to be of advanced age, the visual presentation method seemed more appropriate.

Participants were given 2 sample WMC test items to introduce them to each of the WMC tests; 2 extra sample items were given during the letter-number sequencing task once the size of the spans reached 3 items. Participants were provided with the following instructions: "Now you are going to see some numbers. When the numbers stop, please type them in backwards. For instance, if you saw: 6 - 2, what would you type?" They were then prompted to type into the computer the correct answer minus any dashes (in this case "2 6"). Neither of the sample items was counted toward the participant's final WMC score. During the WMC tests, each digit or letter in the trial was presented on the screen for 1 second, with a blank screen for 1 second of time between each digit and letter. After the visual presentation of the trial, the participant was asked to type in the correct answer based on the current rule (e.g., backwards).

Discontinue criteria for the digit-span backwards and digit-span sequencing was two incorrect trials, and three incorrect trials for the letter-number sequencing task. Once discontinuation criteria were met the computer automatically moved the participant on to the next item. If the participant correctly recalled at least one correct trial in an item, they were then moved onto an item that was 1 digit or letter longer, and therefore more difficult. The digit-span backwards and digit-span sequencing items ranged from 2 (easiest) to 8 (hardest) digits, with 3 trials of 2 digit items, and 2 trials of all other items, resulting in a total of 16 possible sequences. The letter-number sequencing items ranged from 2 (easiest) to 8 (hardest) letter-number combinations, with 6 trials for the 2 letter-number combination items, 9 trials for the 3 letter-number combination items, and 3 trials per remaining item (4, 5, and 6 letter-number combinations), resulting in a total of 30 possible sequences. The final WMC items, including instructions to participants and the logical algorithm used by the computer in the progression of these tests, are presented in Appendix G.

The WMC tests were pilot tested on 30 individuals. During pilot testing, item variability was non-zero and no problematic items were identified; therefore, no changes were made to this instrument prior to beginning data collection. A participant's WMC score was the total number of items they recalled correctly on each of the three span tasks. Given that all three tasks were related and loaded similarly on a single factor (ostensibly WMC), the objective was to use the extracted first-order principle component as a unitary WMC score for use during statistical analyses. A first-order principle component extraction revealed that all three measures loaded heavily on a single factor (Factor loadings: DSB = .80, DSS = .84, LNS = .80), which accounted for 65.97% of the variance in the underlying WMC measures. The single factor was extracted and saved as a standardized regression score for use as a final WMC composite.

Declarative memory

Declarative memory was assessed using a 30-item list of paired grocery items and prices (cue-stem pairs). To develop this test, 30 items were randomly selected from the 52 remaining grocery items and prices from the domain knowledge test. This methodology ensured that items on the declarative memory test did not overlap with the items in the domain knowledge test. The number of items (30) was chosen as it reflects a relative average of items used in similar research designs; for instance, Hambrick and

Engle (2002) used a total of 21 items, while Castel (2005) used a total of 40 in one experiment and 21 in another. Because these studies have also demonstrated that domain knowledge only has a facilitating effect for domain-congruent information, the grocery items selected for inclusion in the declarative memory test were manipulated such that the names of some were changed to be fictitious (noncongruent), while the names of others were unchanged and remained realistic (congruent). To accomplish this manipulation, half of the cue-stem pairs were randomly selected for use as realistic cues, leaving the other half allocated for use as fictitious cues. The ARC online nonword database (Rastle, Harrington, & Coltheart, 2002) was used to create 15 fictitious food names. Each of the fictitious items' phonological and lexical characteristics was based, as closely as possible, on food words. The final names needed to sound like possible foods, be pronounceable, and yet remain outside the English language. These 15 fictitious items were then paired with the prices allocated for use with the fictitious cues. For instance, a participant would have seen:

Loaf of Rhoond: $4.67

Prior to the actual memorization task, participants were given the following instructions: "This next task will involve memorizing a set of prices for various grocery items. There will be 30 items overall. Some of the grocery items will be ones you recognize, while other grocery items you will probably never have heard of before. The prices of each item will vary in length from a few cents to many dollars. You will be given 7 minutes to memorize the entire list. Please do your best to memorize each grocery item and its associated price. In a little while, we are going to ask you to remember as much from this list as possible. Before you move onto the actual memory task, we are going to give you a chance to practice the memory test to see what it's like. After the practice test, you will move onto the actual memory task. Click "next" to try the practice test." For the practice test, participants were then given 4 minutes to memorize a list of 6 cue-stem pairs, half of which were fictitious and half of which were realistic. After the 4 minutes had elapsed, the participant was then asked to try to recall, to the best of their ability, the correct prices associated with each item. Participants were informed that they should try to remember, down to the cents, the correct price. They were presented with a list of the 6 cues and blanks in which they could type the correct stem. For instance: Fish Sticks $______._______. Following the practice recall task, participants were informed: "Now that you've practiced, you are ready to move onto the actual memory task. If you have any questions or are confused, please be sure to ask the researcher! Remember, for the actual memory task, you will have 7 minutes to memorize the information. After the 7 minutes, you will move onto another task." The participant was then presented with the entire list of 30 cue-stem pairs, which the participant was given 7 minutes to memorize. This time limit was based on 2 previous studies involving similar stimuli (Bermingham, Hill, Woltz, & Gardner, 2013; Hill, Schwob, & Ottman, 1993).

During the immediate recall task, the cues were presented in a random order, and participants were queried for the correct stem. The presentation of the cues in a random order was to prevent the participant from having memorized the order of the pairs, rather than the cue-stem pair itself. Participants were required to enter in a stem for each item in order to move on with the study; blank entries for stems were not accepted.

The declarative memory test was pilot tested on 30 individuals. During pilot testing, item variability was non-zero and no problematic items were identified; therefore, no changes were made to this instrument prior to beginning data collection. The final paired 30-item cue-stem list of grocery items and prices is presented in Appendix H.

Each item was scored correct if the participant provided a verbatim answer; no points were given for stems that were close to correct. The amount of time the participant took to complete recall task was recorded; however, the time the participant took responding to each individual item was not recorded. A participant's score on the declarative memory test was the total number of items they correctly recalled verbatim for the realistic and for the fictitious cue-stem pairs. Internal consistency reliability estimates showed that both the realistic and fictitious portions of the test had adequate reliability (Cronbach’s alphas: realistic = .71, fictitious = .69).

A second method of tabulating each individual's score on the recall task was employed for use during supplementary analyses, and was useful in addressing gist-based recall rather than verbatim recall. The absolute difference between the recalled price and the actual price was calculated, thus creating a “distance score” based on the absolute distance a participant’s response was from the actual price. Summed distance scores were calculated for the fictitious and the realistic cue-stem pairs. This approach to scoring moves away from answers being either correct or incorrect, and instead allows for an index of correctness of recall; some responses were closer to correct (reflected in lower scores) than others (reflected in higher scores).

Demographics and strategy use

Participants were queried about their demographic information, including questions about age, number of years of education completed, whether they are the primary shopper for their household, how many people they shop for, and approximately how often they shop per week. The demographic questionnaire is presented in Appendix I.

The participant's use of strategies was assessed using an open-ended form where participants were instructed to "Please list any methods that you used to remember the prices. Feel free to be as detailed as you want to be." This method of self-report was adapted from an approach used in previous research (Bermingham, et al., 2013). Response times on this self-report were not collected. The strategy use questionnaire was pilot tested on 30 individuals. No problems were noted during pilot testing; therefore, no changes were made to this instrument prior to beginning data collection.

To code the use of strategies, a scoring rubric was adapted from research by Devolder and Pressley (1992). Responses were scored on a 5-point scale. A score of 0 indicated no strategy was used and more efficient strategies (i.e., enabling encoding of more cue-stem pairs) were associated with higher scale values. No distinctions were made between types of strategies used (i.e., visual imaginary versus verbal elaboration) in the scheme. Rather, procedures were scored based on how multiple items were linked at encoding. This scoring scheme, along with frequencies of responses given a particular score, is detailed in Table 2. Two independent raters coded participant responses. Inter-rater reliability was strong ($r = .80$). Final determination on the disagreed-upon items was performed by one of the raters.

Table 2

Strategy Use Coding Schema and Frequency Data

Code	Description	*f*
0	No strategy used Example: “I have no method to memorize.”	20
1	Repetition – repeating the cue-stem pairs over and over to oneself. Example: “I went over them saying the name and then the price. Just repeated it over and over.”	40
2	Minimal strategy use – making minor associations among cue-stem pairs; noticing simple patterns, ordering by magnitude, or rounding. Example: “I tried taking the highest priced items and the lowest priced items and remembering that nothing in between will cost more or less, then I imagined the items as I repeatedly went over them.”	58
3	Metacognitive strategy – i.e., self-testing A few good strategies – participant created connections between the cue-stem pairs, but they were used inconsistently. Example: “I first read through the whole list and then went back to the beginning and started to repeat the item and the price over and over again, about four times. I then noticed that some of the prices were the same or similar and so I grouped those together in my head. After I thought I had some of them fairly good, I started to try and test myself on the items, but the time ran out before I could get very far.”	66
4	Multiple strategies – participant created meaningful connections between the cue-stem pairs used consistently. Example: I attempted first to organize them by price low to high. I attempted to create a "story" from some of the items. I used technical "jargon" for some, for example 3.37 flour. "I EET (337) flour." I used math: for example 12 oz of ___ and the price was similar if doubling the oz.	14
5	Formalized mnemonic – i.e., method of loci.	0

Procedures

Participant compensation varied. Individuals recruited for the pilot test were entered into a raffle for one of four $50 gift certificates to a Smith's grocery store. Those individuals who signed up to participate through the University of Utah Educational Psychology Subject Pool were given 1 credit per hour participated toward a research requirement portion of one of their classes. All other participants were given $20 in cash as compensation for their time. All participants were provided with results on how they performed on the domain knowledge, working memory, and declarative memory tasks.

All research was conducted in a quiet and secured computer lab at either 1) the University of Utah Milton Bennion Hall; 2) Columbia College; or 3) Mount Olympus Senior Center in Midvale, Utah. Research performed at the University of Utah was conducted by either the primary investigator or a research assistant who was trained in the protocol; research at the remaining locations was conducted entirely by the primary investigator. Materials were presented via a computer interface. The Mozilla Firefox or Google Chrome web browser was used exclusively for presentation of the study materials as these browsers adhere strictly to web rendering standards. All materials were presented in "full screen" mode so that the URL bar, browser menu, and any other browser or operating system elements were not visible.

The font size on the screen was adjusted as needed so that the participant was able to read the materials, but not so much that page layout was affected. Upon entering the room, the participant was seated at a computer and provided with a printed copy of the consent document, which she was required to read through, sign, and date in order to begin the study.

Next, the participant was given verbal instructions from the experimenter or the research assistant. The participant was informed: "You are about to participate in a study on memory and cognition. The study will be conducted entirely on the computer that is in front of you. Directions are provided throughout and the study should be straightforward. You will find that some of the tasks are easy, while some are more difficult. Also, some of the pages are timed and the computer will automatically switch to the next task after the time limit has run out. You will not see the timer, and if the page switches while you are working on something do not try to go back. At the end of the study, the computer will provide you with results on how you performed. If you have any problems, or any questions at any time, please ask for help. Do you have any questions?" After answering any questions that the participant had, she was directed to continue answering questions on the computer screen.

The participant was then presented with an introduction to the domain knowledge task, including an example of what she would see and instructions on how to complete this task. Next, she was presented with the domain knowledge test and required to answer all 30 items in order to progress with the study.

Upon completion of the domain knowledge test, the participant was introduced to the declarative memory task and given a 4-minute practice test. After the 4-minute practice test, she was then presented with all 30 cue-stem pairs (15 realistic and 15 fictitious) on a single page, and given 7 minutes to memorize them. After the 7 minutes had elapsed, the computer automatically presented the participant with the demographics questionnaire. Immediately following the questions, the participant was instructed to read several paragraphs on an unrelated topic (information about pongids, downloaded from Wikipedia in April of 2012) until a 10-minute interval elapsed. The use of the demographic questionnaire and 10-minute time limit was to prevent the participant from rehearsing the cue-stem pairs, thus acting as a distracter task.

The participant was then presented with the immediate recall task. This consisted of the presentation of the entire list of cues arranged in a random order. The recall task involved entering numbers to replace blanks with the correct stem that corresponded to the cue (e.g., Sugar (5 lbs) $__.__"). The participant was given an unlimited amount of time to complete the recall task, but was required to provide answers to all 30 items on the screen in order to proceed. Following the recall task, the participant was presented with the strategy use questionnaire that asked the participant to detail, using an open-ended form, any methods that she used to remember the prices.

Following the strategy use questionnaire, the participant was introduced to the WMC tasks beginning with the digit-span backwards test starting with the sample items. Once discontinue criteria were met for the digit-span backwards items, the participant proceeded to the digit-span sequencing test starting with the sample items. Again, once discontinue criteria were met, the participant proceeded to the letter-number sequencing test starting with the sample items. Upon meeting the discontinue criterion or completing all the items the WMC task was complete and the participant was debriefed.

Debriefing of the participant involved thanking her for her time and providing her with computer-generated results on how she performed on the various measures. These results included her score on the domain knowledge test, her score on the declarative memory test, and her scores from the WMC tests. The participant was informed that the results were not meant to be diagnostic, but rather to provide her with information about how she performed on the current tasks. She was then asked if she had any questions or concerns about her performance. Finally, the participant was compensated for her time.

CHAPTER III

RESULTS

Data Screening

Prior to analysis, the primary study variables, including the participant's age, domain knowledge score, working memory capacity (WMC) score, and score on the immediate recall task broken down by cue-stem pair type (realistic and fictitious), were examined through various SPSS procedures for accuracy of data entry, missing values, and fit between their distributions and the assumptions of multivariate analysis, including normality, linearity, and homoscedasticity. Aiken and West (1991) suggest that all independent variables should be centered (i.e., scores are transformed to represent a distribution with a mean of 0) prior to the regression analysis. Centering has the primary effect of enabling the variables to have a meaningful 0-point on their scales. Therefore, prior to analysis, the independent variables of age and domain knowledge were mean centered. The WMC composite score was already centered due to being saved as a standardized regression score.

Pilot study data were compared to the main study data to determine if inclusion in the final analysis was appropriate. No significant differences were found between the pilot study data and the main study data with respect to age, domain knowledge, WMC, or declarative memory. Therefore, the pilot study data were included for analysis in the final study.

Three missing values for age were replaced by the mean of all cases. The resulting age variable was strongly positively skewed, positively kurtotic, and bimodal. Several transformations were employed (e.g., natural log, square, and cube root) in an attempt to create a more normal distribution; however, due to the bimodal nature of the distribution, these transformations simply exacerbated the bimodality. Therefore, the age variable was not transformed and left as a skewed and kurtotic distribution.

Two methods were employed for identifying outliers: an approach including visual inspection of histograms and plots, and a data-driven approach (Mertler & Vannatta, 2002; Tabachnick & Fidell, 2001). Univariate outliers were identified first through visual inspection of histograms, and a cutoff of 3 standard deviations was used for exclusion from analysis. Six cases were identified as potential outliers on the domain knowledge measure, having extreme low scores; five of these cases had scores that were 3 standard deviations below the mean and were therefore excluded from analysis. Five cases were identified as potential outliers on the WMC composite, all of which had scores at least 3 standard deviations below the mean, and were therefore excluded from analysis.

With respect to the two measures of declarative memory (fictitious vs. realistic cue-stem pairs), the distance scores (outlined in the materials section) were used as a measure of effort in answering. Distance scores that were extreme (e.g., 3 standard deviations above the mean) were indicative of low effort as they represented guesses that were substantially disparate from the original price. Using these criteria, 3 cases were identified as potential outliers on the fictitious cue-stem pairs, and 2 cases were identified on realistic cue-stem pairs; all were excluded from analysis.

An additional method of visual data screening involved creating scatter-plots of elapsed time x accuracy for the domain knowledge task, and elapsed time x distance score for the declarative memory task, essentially creating proxy measures of effort. Those individuals who had lower scores and took less time on the domain knowledge measure, or who had higher distance scores and took less time on the declarative memory measure, may have been answering randomly, guessing, or putting forth very little effort and therefore finishing more quickly than would be expected. With respect to domain knowledge, 4 cases were identified as potential outliers, with low elapsed times and low scores and excluded from analysis. No outliers were identified using the time x distance score for the declarative memory task. Overall, 14 cases were excluded from analysis based on meeting at least one of the aforementioned screening criteria.

The data-driven approach to identifying outliers involved computing multivariate (Mahalanobis) distance scores, as recommended by Mertler and Vannatta (2002), and Tabachnick and Fidell (2001). Using this method, 8 cases were identified as multivariate outliers ($\chi^2 > 27.877$, $p < .001$).

There was a significant, though weak, relationship between the psychological and data-driven approaches to identifying outliers ($r = .15$, $p = .03$). Ultimately both methods were utilized, resulting in 20 cases that were excluded from data analysis and leaving a final total of 198 cases.

Descriptive Results

Descriptive statistics were computed for the domain knowledge, WMC, and declarative memory tests. Score ranges, means, and standard deviations are all presented in Table 1.

Average participant domain knowledge, assessed on a scale of 0 to 30, was 17.54 (*SD* = 1.95). Internal consistency for this measure using the final sample of 198 participants was low (Cronbach's alpha = .34).

Working memory capacity (WMC) was assessed as a composite of three WMC subtests, and was interpreted as a z-score with a mean of 0 and a standard deviation of 1. Raw WMC subtest scores are also summarized in Table 1. Ceiling effects were observed on the digit-span backward and digit-span sequencing subtests. With the final sample of 198 participants, the principle component extracted accounted for 67.32% of the variance in the underlying WMC measures.

As part of Table 1, declarative memory is summarized and broken down into averages for the 15 realistic 15 fictitious cue-stem pairs. As expected, the realistic stems were recalled more accurately (*M* = 3.76, *SD* = 2.72) than were fictitious stems (*M* = 1.92, *SD* = 1.99). Substantial floor effects were observed for both realistic and fictitious measures: 62 participants (31%) scored 0 on the fictitious measure, while 18 participants (9%) scored 0 on the realistic measure. Gist-based recall, assessed using the absolute deviation between the recalled stem and the actual stem (distance score), also favored the realistic stems (*M* = 7.46, *SD* = 3.46) compared to the fictitious stems (*M* = 15.80, *SD* = 5.15). Internal consistency for these measures using the final sample of 198 participants was adequate (Cronbach's alphas: Realistic pairs = .72; Fictitious pairs = .68).

Frequency data for the coded responses on participant's use of cognitive strategies are presented in Table 2. Of note, no participants reported using formalized mnemonics. Also, the frequency distributions across types of strategies used was highly variable (i.e., 66 vs. 14); therefore, it was determined that these data would not be useful as a categorical variable during statistical analysis. Histograms representing the average recall of fictitious and realistic cue-stem pairs as a function of type of strategy used are presented in Figures 2 and 3. As can be seen in these figures, the more efficient strategies were associated with higher rates of recall. This gradation was more pronounced for the fictitious cue-stem pairs than for the realistic cue-stem pairs. Frequency data for the demographic questions related to shopping behaviors are presented in Table 3. Of note, the frequency distributions across categories for these questions were highly variable; therefore, it was determined that these data would not be useful as categorical variables for exploratory analyses.

Intercorrelations

For all statistical tests, an alpha level of .05 was used. Pearson product moment correlations among all measures and specific demographics variables were calculated and are presented in Table 4. As expected, age was negatively related to WMC as well as with recall of fictitious cue-stem pairs. Age was also negatively related to recall of realistic cue-stem pairs; however, this relationship was not significant. Age was positively related to domain knowledge. Older individuals were also more likely to do most of the shopping for their household, and go shopping more often.

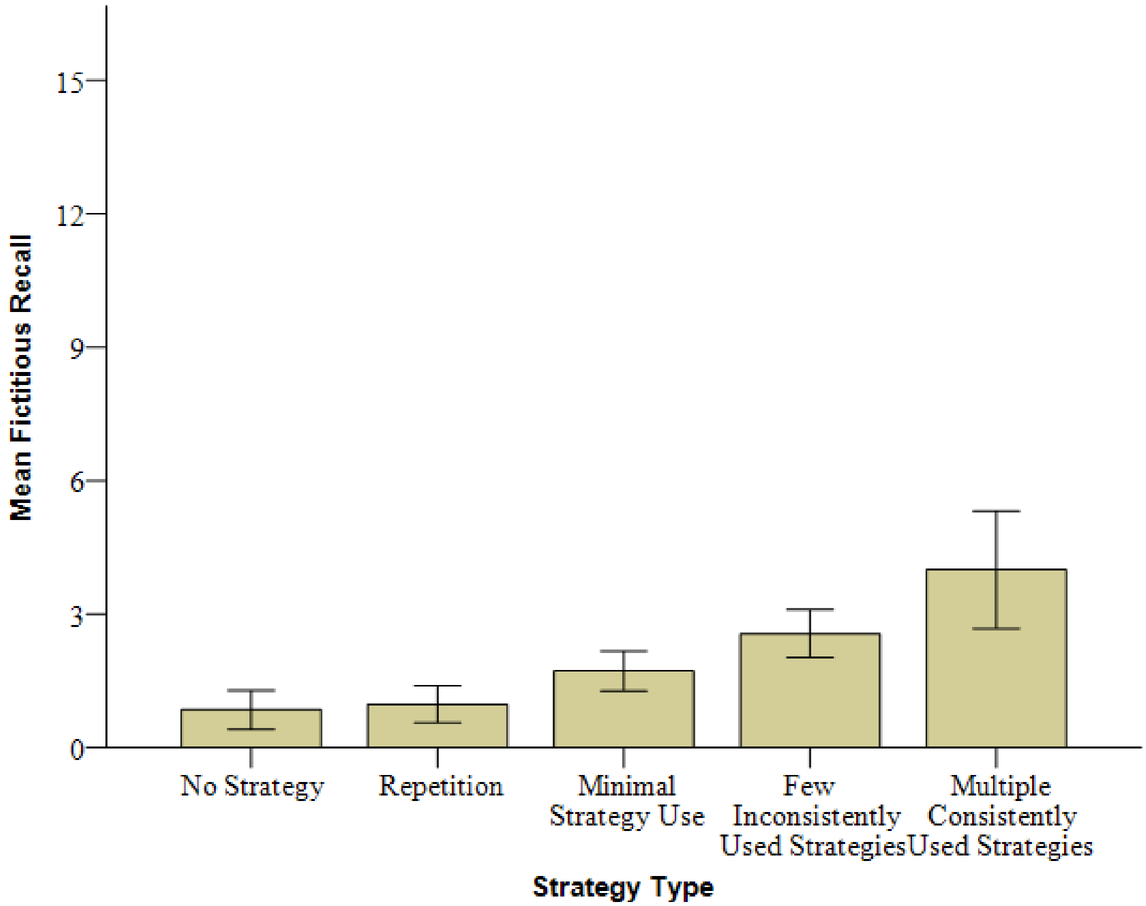

Figure 2: Mean fictitious recall as a function of type of strategy used.

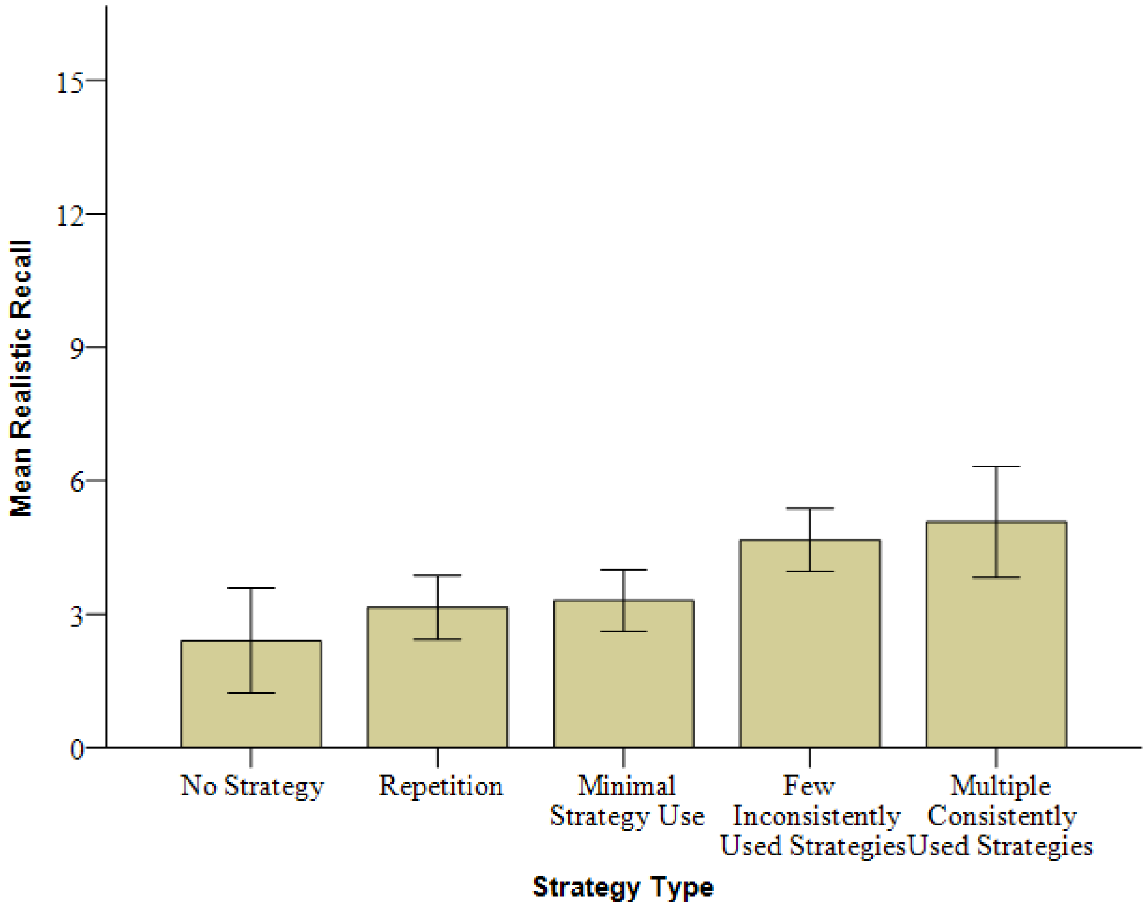

Figure 3: Mean realistic recall as a function of type of strategy used.

Table 3

Frequency Data from Demographic Questionnaire Grocery Shopping Behaviors

Variable	*f*
Are you the person who does most of the grocery shopping for your household?[a]	
Yes	69
No	126
Approximately how many times a week would you say you go grocery shopping for your household?[b]	
I do not do the grocery shopping	31
1 or less times per week	117
2-3 times per week	46
Nearly every day	2
How many people do you shop for in your household?[c]	
Myself	62
2 people	59
3 people	25
4 people	20
5 people	14
6 or more people	11

a. 3 missing responses
b. 2 missing responses
c. 7 missing responses

Table 4

Correlation Coefficients for Selected Study Variables

	1.	2.	3.	5.	6.	7.	8.	9.	10.
1. Age									
2. Domain Knowledge	.28**								
3. WMC[a]	-.31**	.01							
5. Realistic Items	-.08	.19**	.36**						
6. Fictitious Items	-.23**	.07	.46**	.50**					
7. Realistic Distance Score[b]	-.01	-.14*	-.16*	-.50**	-.26**				
8. Fictitious Distance Score[b]	.10	-.04	-.31**	-.26**	-.65**	.16*			
9. Do you do most of the shopping?	.30**	.21**	-.03	.03	.01	-.16*	-.10		
10. How often do you go grocery shopping?	.33**	.22**	-.05	-.02	-.14*	-.13	.10	.59**	
11. How many people do you shop for in your household?	.09	-.01	.04	.08	-.02	.02	-.03	-.34**	-.05

* $p < .05$, ** $p < .01$

a. The WMC composite was created using the WMC subscales (DSB, DSS, and LNS) and was transformed into a composite through a first-order principle components extraction creating a mean-centered variable that is interpreted as a z-score.

b. The distance score was calculated as the absolute deviation between the recalled price and the actual price. Higher scores represent poorer overall recall.

As expected, domain knowledge was positively related to realistic cue-stem pairs, and had no relationship with fictitious cue-stem pairs. Similarly, more domain knowledge was related to lower distance scores for the realistic cue-stem pairs, and was unrelated to the distance score for fictitious cue-stem pairs. Additionally, those individuals who reported doing most of the grocery shopping, or who shopped more frequently, also had higher levels of domain knowledge.

Working memory capacity (WMC) was positively related to recall of both realistic and fictitious cue-stem pairs, though more strongly with the fictitious pairs. A similar relationship was found between WMC and lower distance scores for the realistic and fictitious cue-stem pairs, again favoring the fictitious pairs.

With respect to the declarative cue-stem pairs, recall of fictitious and realistic pairs had a strong, positive relationship. Realistic and fictitious pairs also had strong negative relationships with their respective distance scores, and weaker negative relationships with their opposite distance scores. Recall of fictitious cue-stem pairs was negatively related to how often an individual went shopping. The distance score for realistic pairs was negatively related to whether the individual did most of the grocery shopping for her household.

Statistical Analysis

To test the proposed moderation models, the effects of age, domain knowledge, and working memory capacity (WMC) were tested with a repeated measures analysis of covariance. The two types of declarative memory pairs (realistic vs. fictitious) represented the repeated measure dependent variable. These two measures were transformed with orthogonal contrasts to represent the average recall (i.e., an overall recall score) and differential recall (i.e., the difference between realistic and fictitious items). Age, domain knowledge, and WMC, and all two- and three-way interactions among these variables were used as covariates. Main effects of age and domain knowledge were predicted for the difference in recall, while main effects of age and WMC were predicted for average recall. The domain knowledge x age, and domain knowledge x WMC interactions tested the predictions that domain knowledge moderated the impact of age or WMC on recall for realistic and fictitious prices, respectively. A three-way interaction (domain knowledge x age x WMC) tested the prediction that domain knowledge moderated the impact of age and WMC simultaneously. Observed power was calculated for all main and interaction effects, and is presented in Table 5.

With respect to differential recall, as expected, there was a large effect for type of item, $F(1,190) = 97.43$, MSE = 2.96, $p < .001$, $\eta_p^2 = .34$. As seen in Table 1, recall performance was higher for the realistic cue-stem pairs than for the fictitious cue-stem pairs. Domain knowledge interacted weakly with item type, $F(1,190) = 4.13$, MSE = 2.96, $p = .04$, $\eta_p^2 = .02$, and as seen in Figure 4, had a facilitating effect on recall for realistic cue-stem pairs. No other interaction effects were significant with respect to type of cue-stem pair.

Table 5

Observed Power for all Main and Interaction Effects from Statistical Tests

Primary Analysis	Observed Power
Differential Recall	
Type[a]	*1.00
Type[a] x Age	0.29
Type[a] x WMC	0.05
Type[a] x Knowledge	*0.53
Type[a] x Age x WMC	0.30
Type[a] x Age x Domain Knowledge	0.05
Type[a] x WMC x Domain Knowledge	0.10
Type[a] x Age x WMC x Domain Knowledge	0.30
Overall Recall	
Age	0.17
WMC	*1.00
Domain Knowledge	*0.76
Age x WMC	0.10
Age x Domain Knowledge	0.06
WMC x Domain Knowledge	0.12
Age x WMC x Domain Knowledge	0.10
Supplementary Analysis	**Observed Power**
Differential Recall	
Type[a]	*1.00
Type[a] x Age	0.28
Type[a] x WMC	*0.75
Type[a] x Domain Knowledge	0.17
Type[a] x Age x WMC	0.38
Type[a] x Age x Domain Knowledge	0.32
Type[a] x WMC x Domain Knowledge	0.49
Type[a] x Age x WMC x Domain Knowledge	0.20
Overall Recall	
Age	0.07
WMC	*0.99
Domain Knowledge	0.26
Age x WMC	0.13
Age x Domain Knowledge	0.08
WMC x Domain Knowledge	0.05
Age x WMC x Domain Knowledge	0.06

* Power was sufficient to detect an effect

a. "Type" Refers to cue-stem pair type: realistic or fictitious

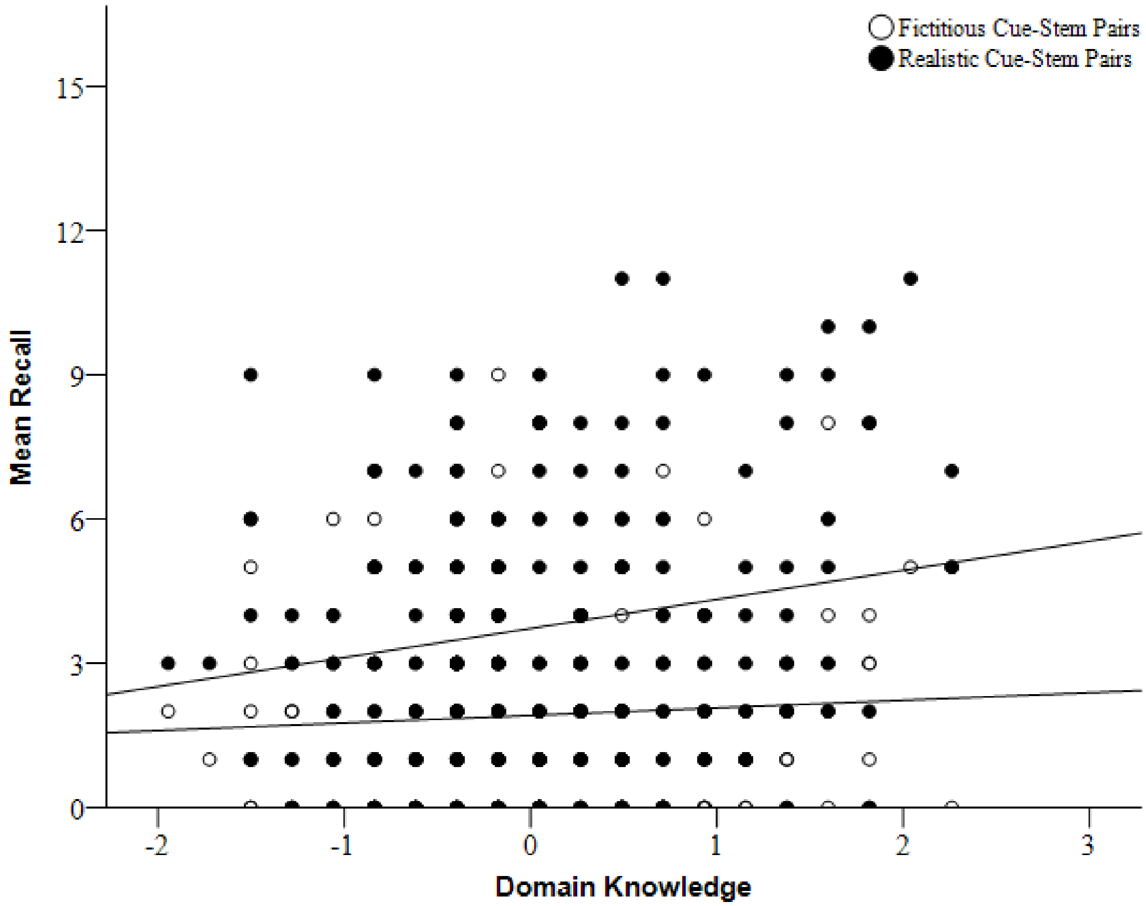

Figure 4: Scatter-plot of domain knowledge x item type interaction. Domain knowledge has been mean centered and is represented as a z-score.

With respect to overall recall, there was a small but significant effect of domain knowledge, $F(1, 190) = 7.23$, MSE = 6.49, $p < .01$, $\eta_p^2 = .04$. There was also a larger main effect of WMC, $F(1, 190) = 35.13$, MSE = 6.49, $p < .001$, $\eta_p^2 = .16$. These results are presented graphically in Figures 5 and 6. No other simple or interactive effects were significant with respect to overall recall.

Supplementary Analysis

A supplementary analysis was conducted to assess whether gist-based recall of the declarative memory cue-stem pairs, compared to verbatim recall, was impacted by age, domain knowledge, or WMC. To accomplish this supplementary analysis, the effects of age, domain knowledge, and working memory capacity (WMC) were tested with a repeated measures analysis of covariance. The two types of declarative memory pairs (realistic vs. fictitious), assessed this time as distance scores, represented the repeated measure dependent variable. These two measures were transformed with orthogonal contrasts to represent the average recall (i.e., an overall recall score) and the difference between realistic and fictitious items. Age, domain knowledge, and WMC, and all two- and three-way interactions among these variables were used as covariates. Main effects of age and domain knowledge were predicted for the difference in recall, while main effects of age and WMC were predicted for average recall. The domain knowledge x age and domain knowledge x WMC interactions tested the predictions that domain knowledge moderated the impact of age or WMC on recall for realistic and fictitious prices.

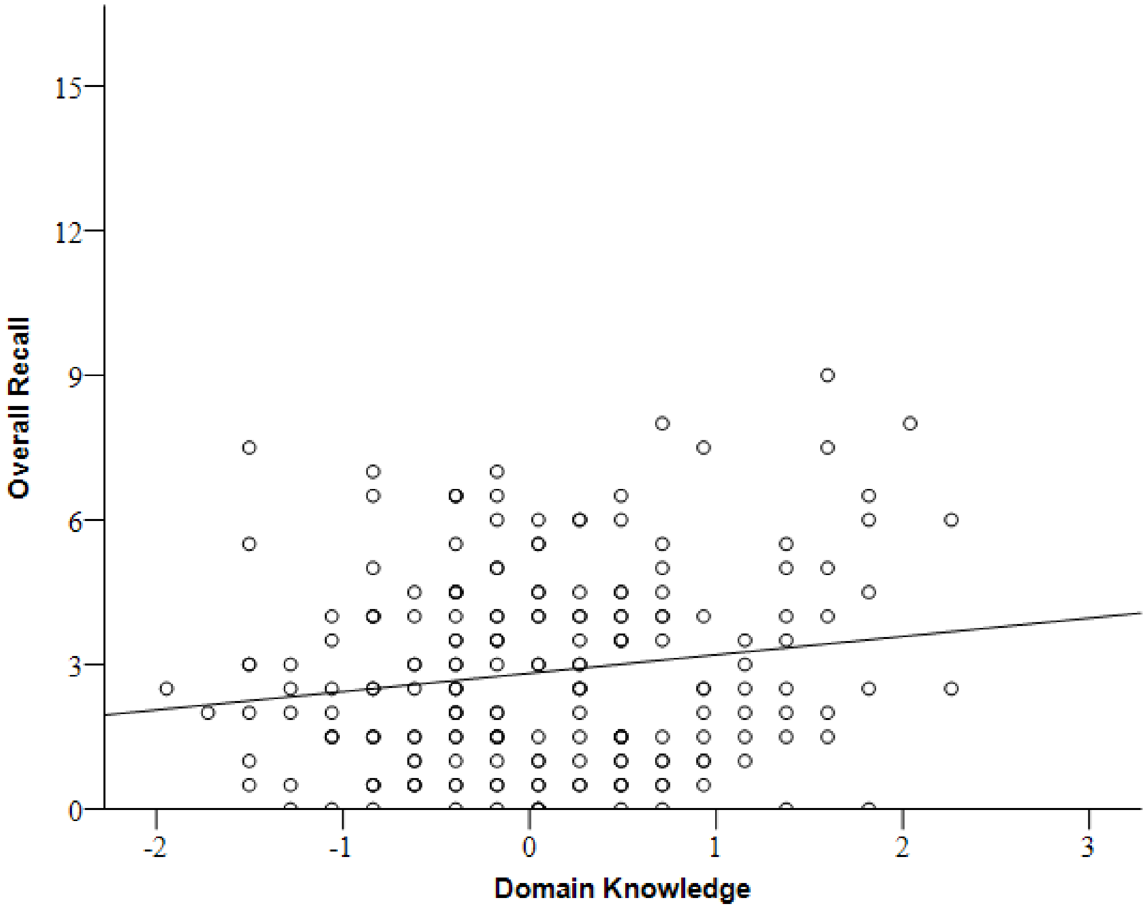

Figure 5: Scatter-plot of domain knowledge vs. overall recall. Domain knowledge has been mean centered and is represented as a z-score. Overall recall represents the average recall of realistic and fictitious cue-stem pairs.

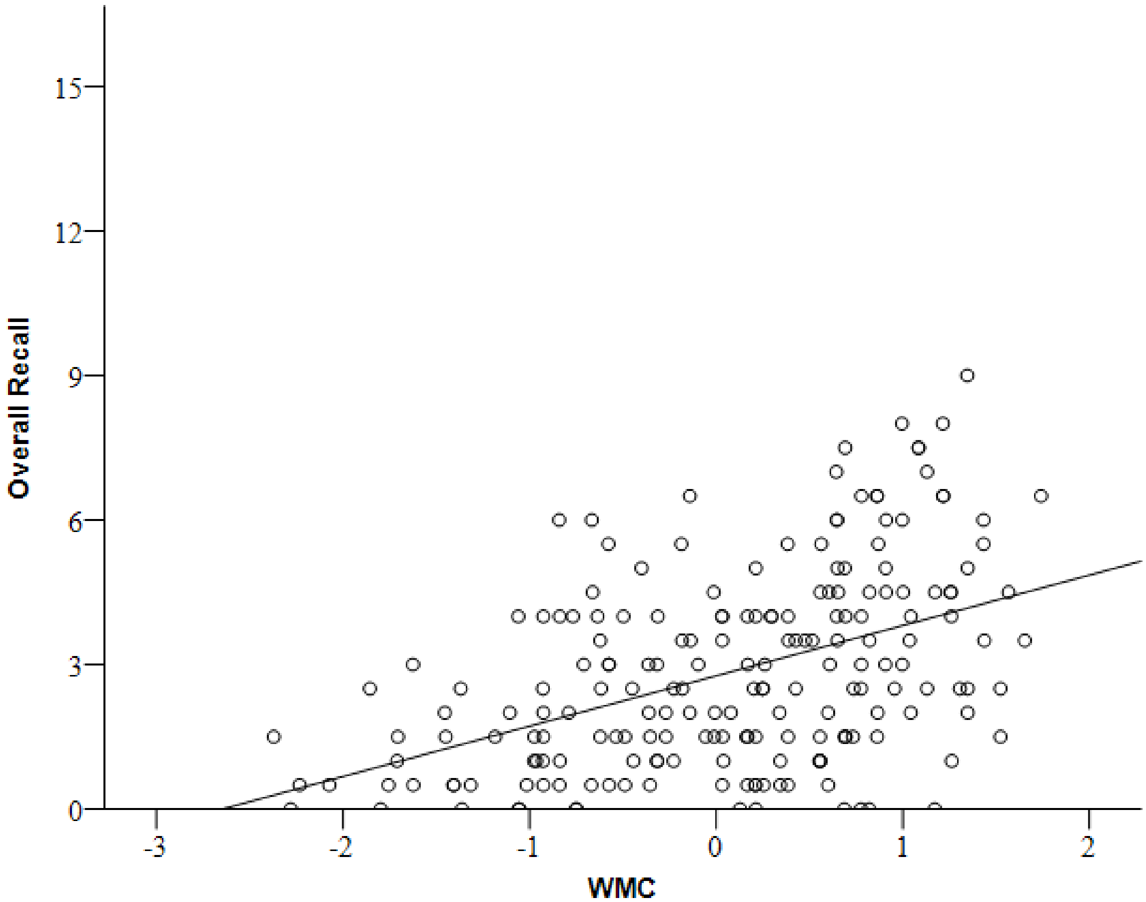

Figure 6: Scatter-plot of working memory capacity vs. overall recall. The WMC composite was created using the WMC subscales (DSB, DSS, and LNS), which were transformed into a composite through a first-order principle components extraction creating a mean-centered variable that is interpreted as a z-score. Overall recall represents the average recall of realistic and fictitious cue-stem pairs.

A three-way interaction (domain knowledge x age x WMC) tested the prediction that domain knowledge moderated the impact of age and WMC simultaneously. Observed power was calculated for all main and interaction effects, and is presented in Table 4.

As expected, there was a large effect for type of item, $F(1,190) = 389.9$, MSE = 15.63, $p < .001$, $\eta_p^2 = .67$. As seen in Table 1, recall performance was higher (lower distance scores) for the realistic cue-stem pairs than for the fictitious cue-stem pairs. Working memory capacity interacted weakly with item type, $F(1,190) = 6.96$, MSE = 15.63, $p = .009$, $\eta_p^2 = .04$, and as can be seen in Figure 7, had a facilitating effect on recall of realistic over fictitious cue-stem pairs. No other interaction effects were significant with respect to type of declarative memory cue-stem pair.

With respect to overall distance scores, there was a small but significant main effect of working memory capacity, $F(1, 190) = 19.81$, MSE = 20.08, $p < .001$, $\eta_p^2 = .09$, as seen in Figure 8. No other simple or interactive effects were significant.

Exploratory Analyses

Exploratory analyses were conducted to determine whether alternative methods of assessing domain knowledge would provide a more reliable measure. These approaches included removing items from the domain knowledge measure that had low or negative item-total correlations and creating a composite measure of cognitive and behavioral indices of domain expertise.

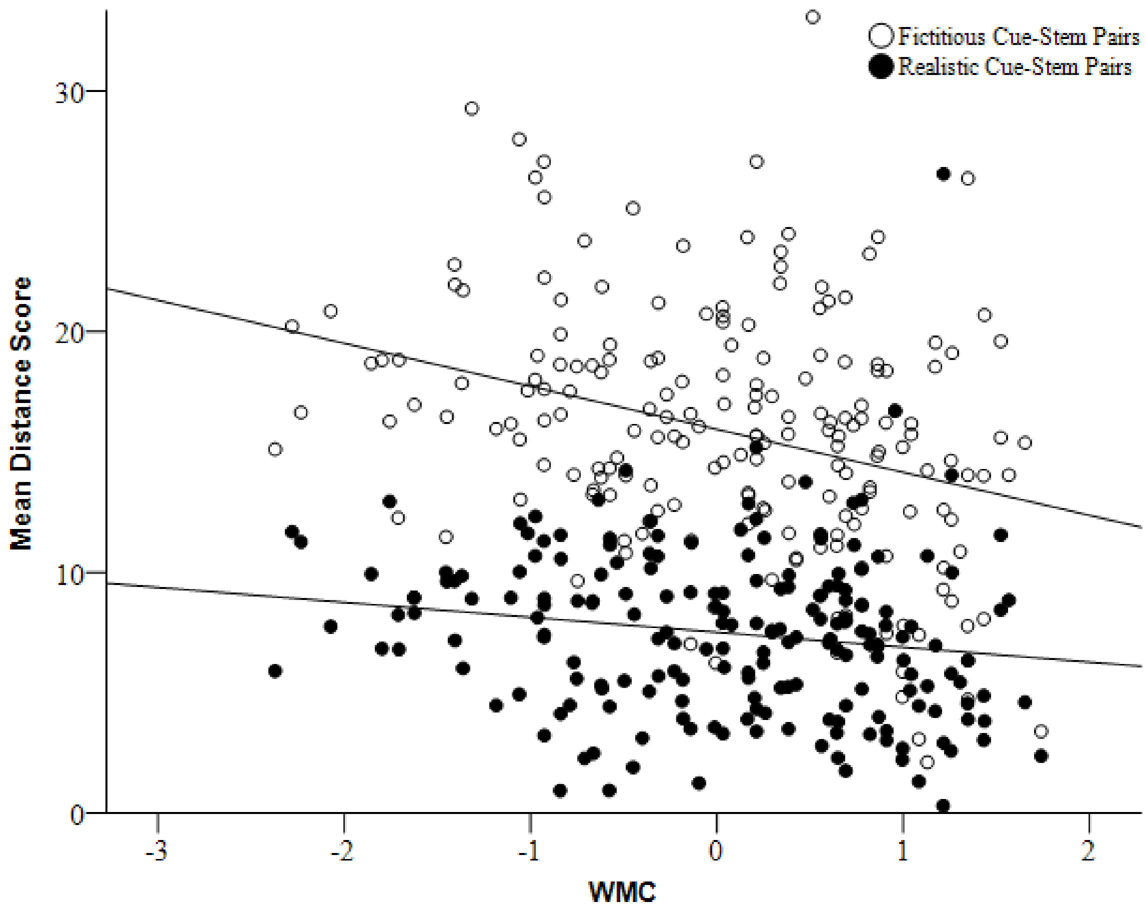

Figure 7: Scatter-plot of working memory capacity x item type interaction. The WMC composite was created using the WMC subscales (DSB, DSS, and LNS), which were transformed into a composite through a first-order principle components extraction creating a mean-centered variable that can be interpreted as a z-score. The distance score was calculated as the absolute deviation between the recalled price and the actual price. Higher scores represent poorer overall recall.

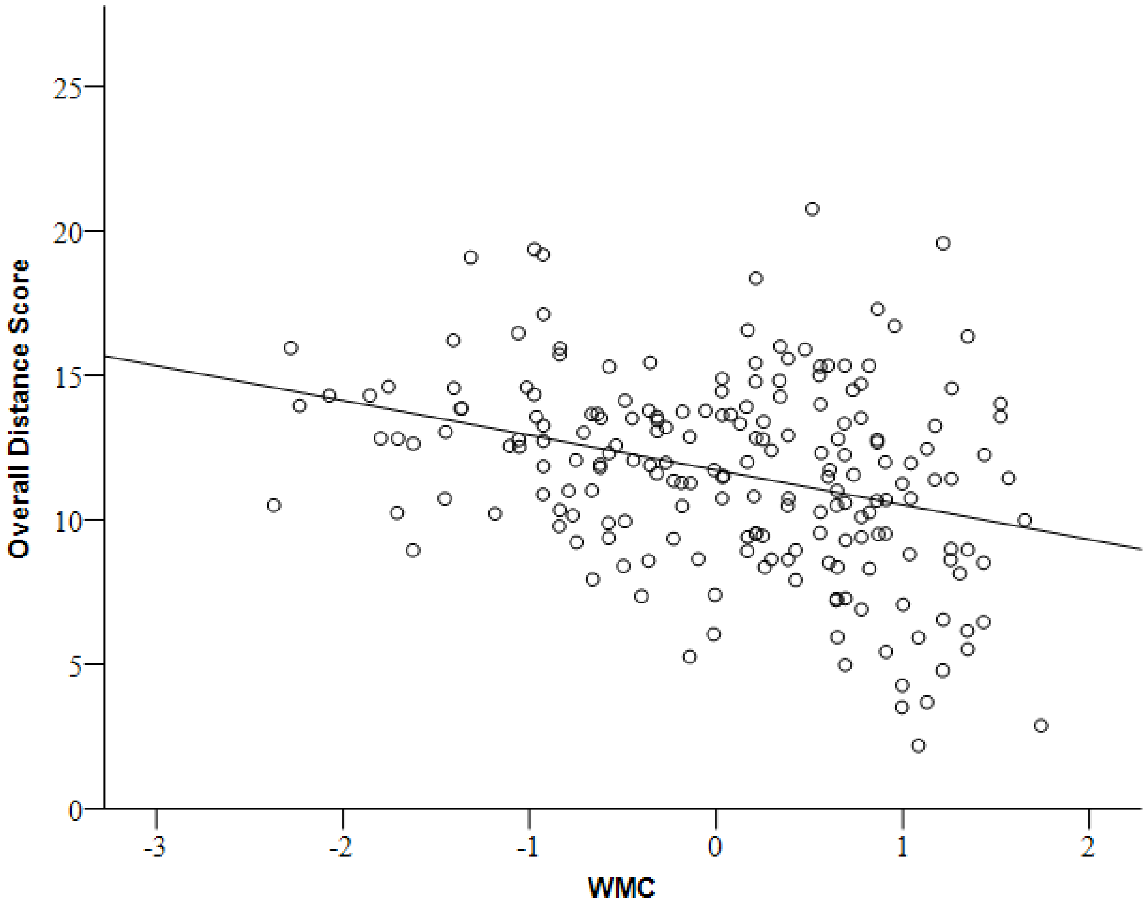

Figure 8: Scatter-plot of working memory capacity vs. overall distance score. The WMC composite was created using the WMC subscales (DSB, DSS, and LNS), which were transformed into a composite through a first-order principle components extraction creating a mean-centered variable; this should be interpreted as a z-score. The distance score was calculated as the absolute deviation between the recalled price and the actual price. Higher scores represent poorer overall recall.

Because the domain item measure had low internal consistency reliability, those items within the measure that had low or negative item-total correlations were removed as an attempt to boost internal consistency reliability. A total of 20 items were removed, resulting in an increased Cronbach's alpha of .58. After rescreening the data (as outlined in the data screening section above) and removing 20 outliers, Cronbach's alpha for the revised domain knowledge measure was .47, slightly higher than previously (Cronbach's alpha = .34).

The literature on expertise and domain knowledge includes both behavioral (i.e., amount of time spent engaging in a task; Castel, 2005; 2007) as well as cognitive (i.e., knowledge; Hambrick & Engle, 2002) measures, which ostensibly tap into procedural and declarative memory processes, respectively. Therefore, self-reported frequency of shopping (reported in Table 1) was combined with the domain knowledge measure to create a composite index of participants' overall domain knowledge as an attempt to create a more reliable measure. A first-order principle component extraction revealed that these two measures loaded heavily on a single factor (Factor loadings for both measures = 77), which accounted for 58.5% of the variance in the underlying composite revised domain knowledge measure. This single factor was extracted and saved as a standardized regression score. Because two people omitted responses to the behavioral measure, the number of participants who had a composite domain knowledge score was 216; after removing outliers, a total of 196 revised composite domain knowledge scores were used.

The primary and supplementary repeated measure analyses of covariance were then rerun with the revised domain knowledge composite (the 20-item domain knowledge measure with a higher coefficient alpha combined with the self-reported frequency of shopping), age, WMC, and all 2-, 3-, and 4-way interactions as covariates. The dependent variables were the recall scores for the realistic and fictitious cue-stem pairs, and realistic and fictitious distance scores, respectively.

For the primary analyses and with respect to differential recall, there was an expected large main effect of type of item, $F(1,188) = 98.41$, MSE = 2.93, $p < .001$, $\eta_p^2 = .34$. The revised domain knowledge composite interacted weakly with type of item, $F(1,188) = 5.00$, $p = .046$, $\eta_p^2 = .02$, and as seen in Figure 9 had a facilitating effect on recall for realistic cue-stem pairs. No other main or interaction effects were significant with respect to type of cue-stem pair.

With respect to overall recall, there was a strong main effect of working memory capacity, $F(1,188) = 27.81$, MSE = 6.63, $p < .001$, $\eta_p^2 = .13$. These results are presented graphically in Figure 10. No other main or interaction effects were significant with respect to overall recall.

For the supplementary analysis of gist-based recall using distance scores, with respect to differential recall, there was again a large effect for type of item, $F(1,188) = 381.28$, MSE = 15.76, $p < .001$, $\eta_p^2 = .67$. The revised domain knowledge composite interacted weakly with type of item, $F(1,188) = 4.00$, $p = .048$, $\eta_p^2 = .02$, and as seen in Figure 11 had a facilitating effect on the distance score for realistic cue-stem pairs. WMC interacted weakly with type of item, $F(1,188) = 4.70$, $p = .031$, $\eta_p^2 = .03$, and as seen in Figure 12 had a facilitating effect on distance score for realistic cue-stem pairs.. Finally, a weak three-way interaction was found between the revised domain knowledge composite, WMC, and type of item, $F(1,188) = 4.08$, $p = .045$, $\eta_p^2 = .02$. These results

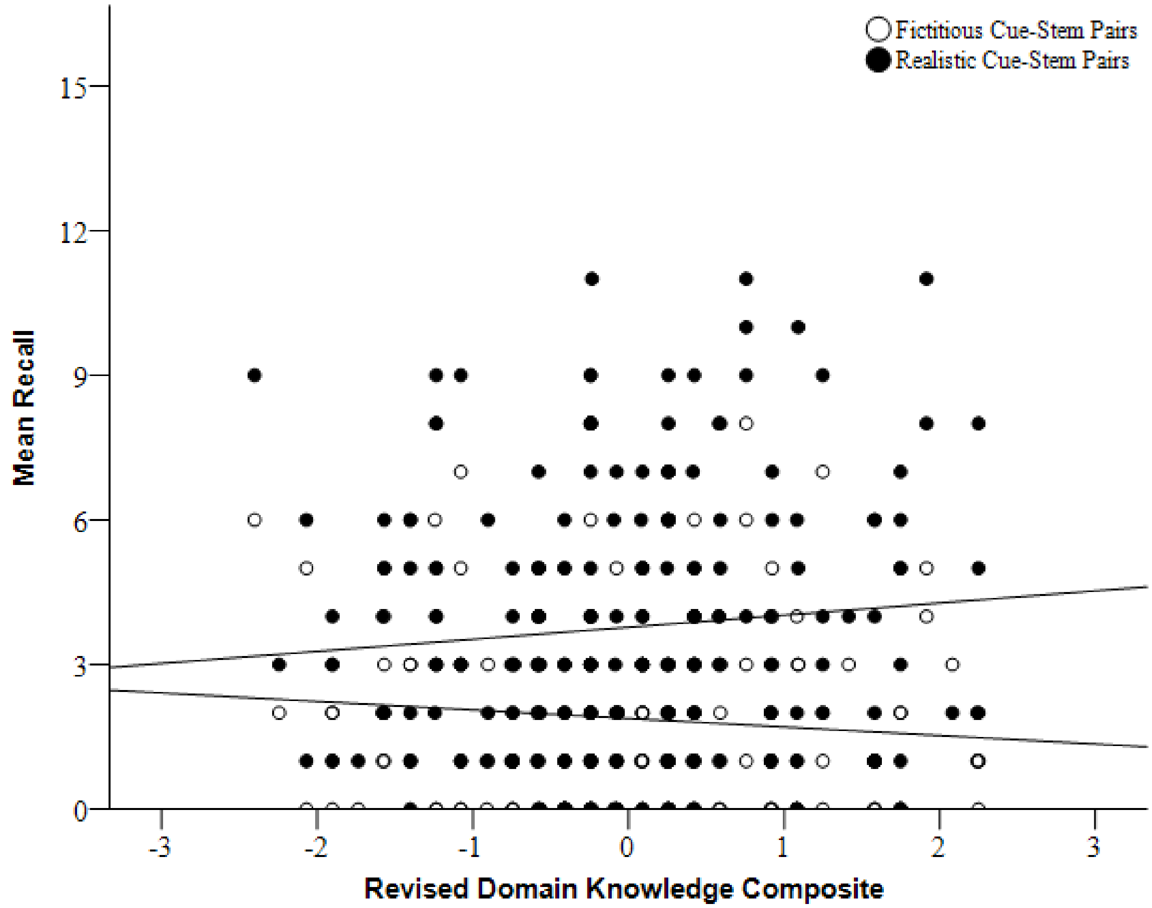

Figure 9: Scatterplot of revised domain knowledge composite x item type interaction. The revised domain knowledge composite was created using the revised domain knowledge measure (20 items, Cronbach's alpha = .47) and the self-reported frequency of shopping question, and was transformed into a composite through a first-order principle components extraction creating a mean-centered variable that is interpreted as a z-score.

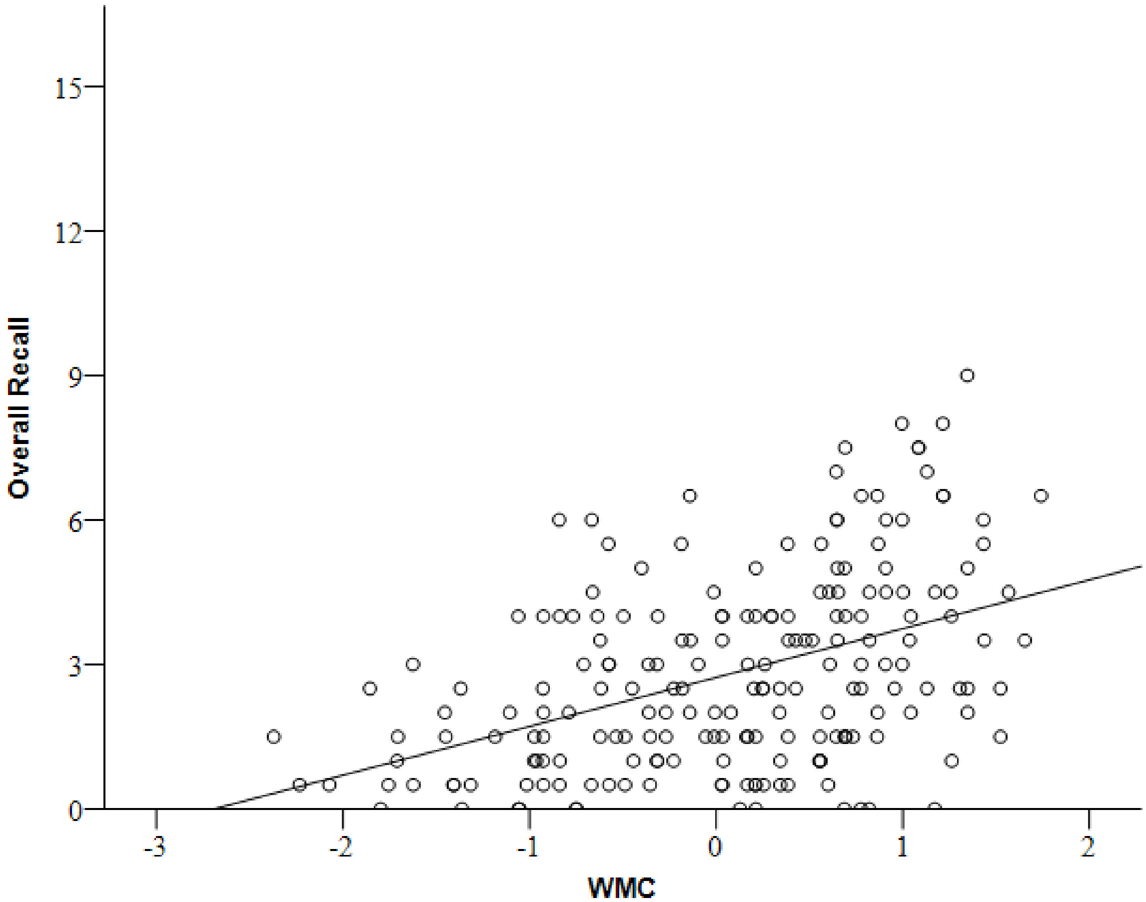

Figure 10: Scatter-plot of working memory capacity vs. overall recall. The WMC composite was created using the WMC subscales (DSB, DSS, and LNS), which were transformed into a composite through a first-order principle components extraction creating a mean-centered variable that is interpreted as a z-score. Overall recall represents the average recall of realistic and fictitious cue-stem pairs.

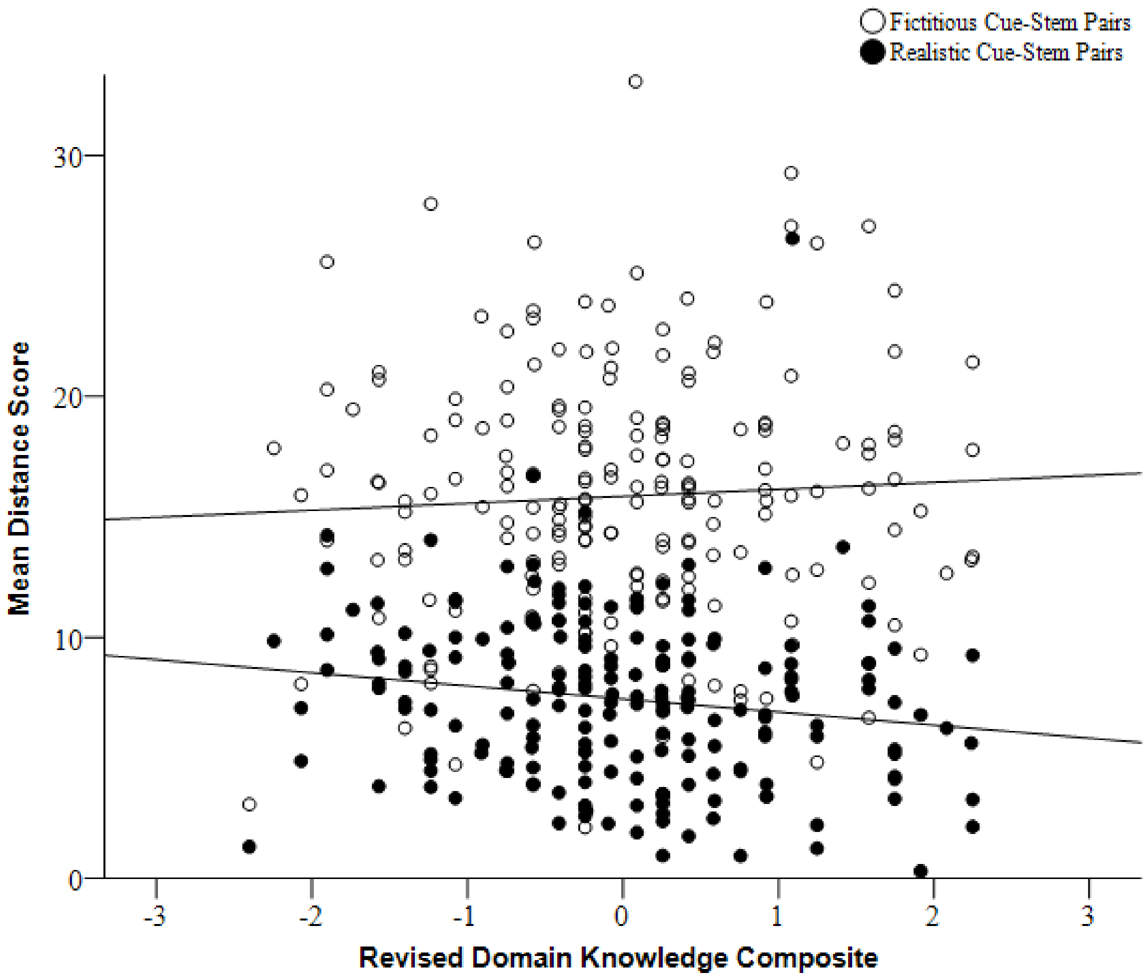

Figure 11: Scatterplot of revised domain knowledge composite x item type interaction. The revised domain knowledge composite was created using the revised domain knowledge measure (20 items, Cronbach's alpha = .47) and the self-reported frequency of shopping question, and was transformed into a composite through a first-order principle components extraction creating a mean-centered variable that is interpreted as a z-score. The distance score was calculated as the absolute deviation between the recalled price and the actual price. Higher scores represent poorer overall recall.

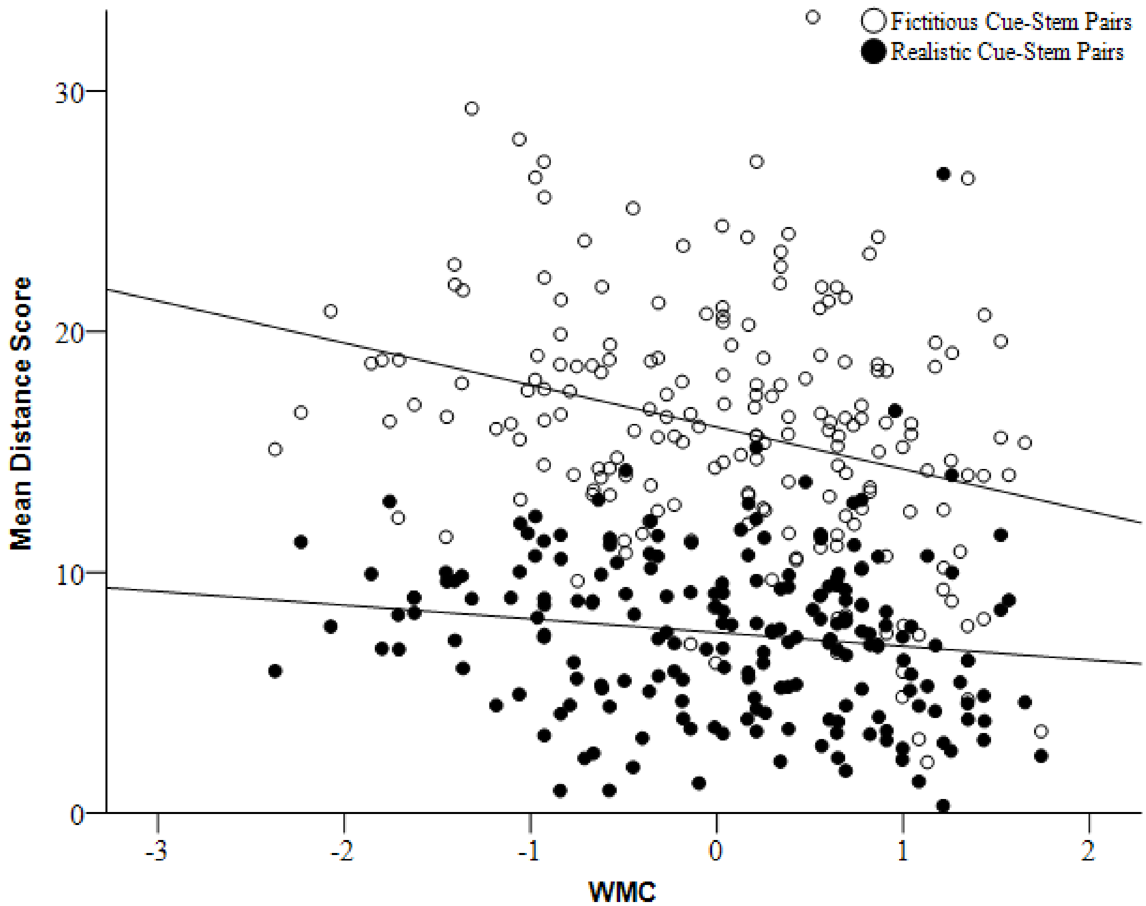

Figure 12: Scatterplot of working memory capacity x item type interaction. The WMC composite was created using the WMC subscales (DSB, DSS, and LNS), which were transformed into a composite through a first-order principle components extraction creating a mean-centered variable that is interpreted as a z-score. The distance score was calculated as the absolute deviation between the recalled price and the actual price. Higher scores represent poorer overall recall.

are presented graphically in Figure 13, and each panel breaks WMC down into quartiles in order to better display the relationship across all three continuous variables. Briefly, domain knowledge facilitated better gist recall (lower distance scores) of realistic cue-stem pairs at the lowest two quartiles of WMC, and this effect was most pronounced for the 2nd quartile (low-medium) of WMC. Domain knowledge did not facilitate recall of either type of cue-stem pair distance score at the highest two quartiles of WMC. No other main or interactive effects were found with respect to type of cue-stem pair distance score.

With respect to overall recall, there was a small but significant effect of WMC, $F(1,188) = 14.39$, MSE = 20.55, $p < .001$, $\eta_p^2 = .07$. These results are presented graphically in Figure 14.

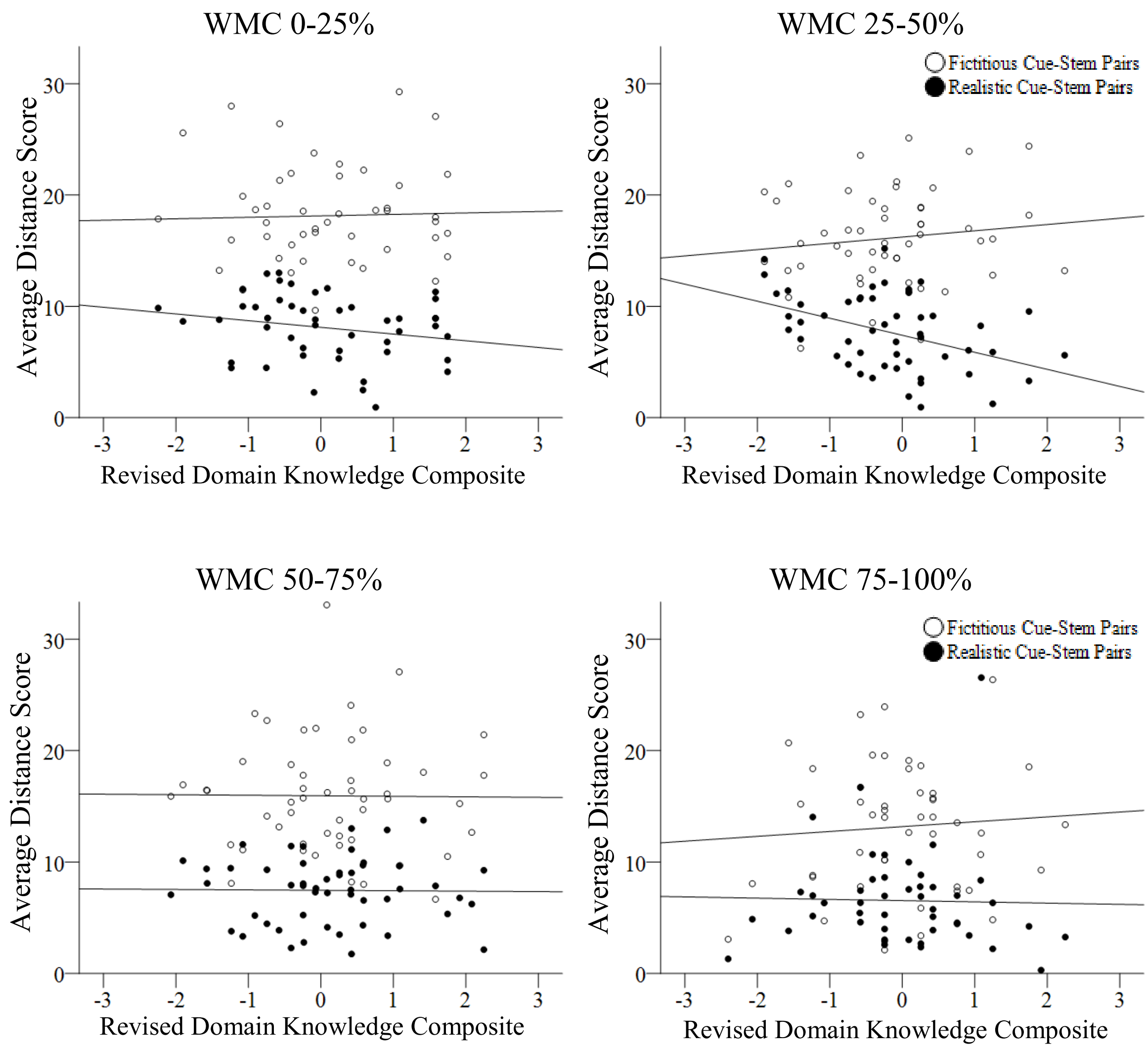

Figure 13: Scatterplots of working memory capacity x revised domain knowledge composite x item type interaction. Each panel represents a quartile of the WMC composite. The WMC composite was created using the WMC subscales (DSB, DSS, and LNS), which were transformed into a composite through a first-order principle components extraction creating a mean-centered variable that can be interpreted as a z-score. The revised domain knowledge composite was created using the revised domain knowledge measure (20 items, Cronbach's alpha = .47) and the self-reported frequency of shopping question, and was transformed into a composite through a first-order principle components extraction creating a mean-centered variable that is interpreted as a z-score. The distance score was calculated as the absolute deviation between the recalled price and the actual price. Higher scores represent poorer overall recall.

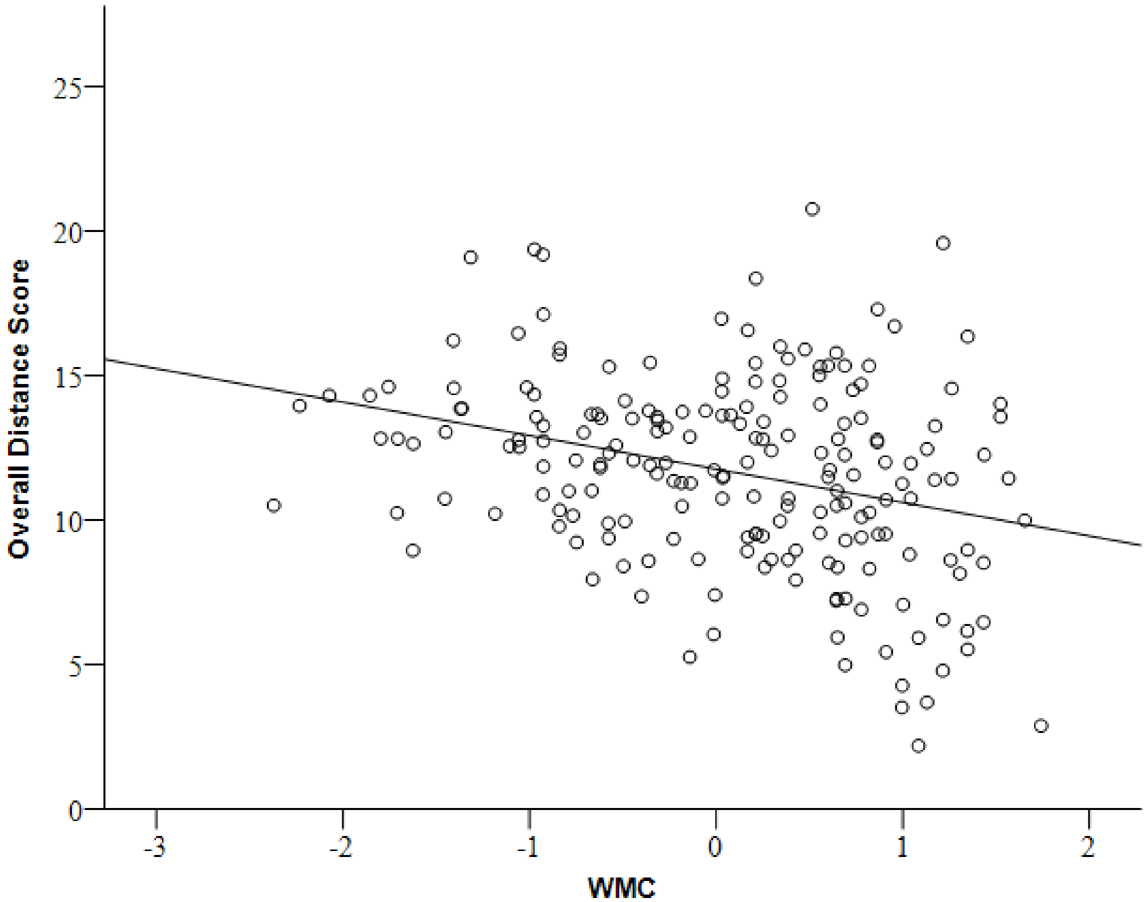

Figure 14: Scatter-plot of working memory capacity vs. overall distance score. The WMC composite was created using the WMC subscales (DSB, DSS, and LNS), which were transformed into a composite through a first-order principle components extraction creating a mean-centered variable that is interpreted as a z-score. The distance score was calculated as the absolute deviation between the recalled price and the actual price. Higher scores represent poorer overall recall.

CHAPTER IV

DISCUSSION

General Discussion

The main aim of this study was to test Hambric and Engle's (2002) proposed models that describe how domain knowledge could potentially moderate the interaction between age or working memory, and recall of domain-specific information. Three possible moderation models were tested: an under-additive model, an additive model, and an over-additive model. Following the recommendations of Hess (2005), this study used a domain that is contextually salient to a general population; namely, knowledge and recall of prices in a grocery shopping domain. Recall was measured using a measure of declarative memory for fictitious and realistic grocery items and their prices (cue-stem pairs), and analyzed as overall recall (i.e., memory averaged across realistic and fictitious cue-stem pairs) as well as differential recall (i.e., the difference between recall of cue-stem pairs). Additionally, and as an exploratory step, participants were queried about strategies they used to assist with memorizing and recalling the cue-stem pairs. The sample of participants consisted of 218 women from the University of Utah and the general community; after data screening, the sample was 198 women.

With respect to a-priori predictions, age was negatively related to recall of fictitious cue-stem pairs but not realistic ones. This is surprising as advanced age is typically associated with poorer recall overall and therefore, the type of information should not make a difference. As expected, age was negatively related to WMC. This effect is found frequently throughout the literature (Craik, et al., 1995; Foos & Goolkasian, 2010; Hedden & Gabrieli, 2004; Hester, et al., 2004; Salthouse, 1994; Schneider-Garces, et al., 2009), and is likely reflective of normal aging processes that decrease cognitive resources (Craik, 1977; Craik, 1986; Craik & Byrd, 1982; Craik & Jennings, 1992) or the speed of cognition (Salthouse, 1996).

Older individuals were more likely to do most of the shopping for their households and go shopping more often. Consequently, it is unsurprising that age was positively related to greater levels of domain knowledge, as the extant literature would suggest greater experience within a domain would result in more domain knowledge (Bors & MacLeod, 1996; Hambrick, 2005), and advanced age would naturally predispose some individuals to having more shopping experience.

As expected, greater levels of domain knowledge were positively related to recall of realistic cue-stem pairs but not related to recall of fictitious cue-stem pairs. Indeed, while the difference in average recall scores between realistic and fictitious cue-stem pairs was relatively small, the size of this effect was quite large. This suggests that participants' knowledge of typical grocery item names or prices substantially influenced later recall. Of note, those individuals who did most of the shopping for their household or went shopping more often had greater amounts of domain knowledge. As mentioned, more experience within a domain would potentially lead to greater amounts of domain knowledge (Bors & MacLeod, 1996; Hambrick, 2005). Working memory capacity was more strongly related to the recall of both realistic and fictitious cue-stem pairs than was domain knowledge.

The primary purpose of this study was to test which of Hambrik and Engle's (2002) descriptive models best described the relationship between age, WMC, and domain knowledge when the domain being studied was relevant to an aging population. The present study found that age had no impact on overall recall or differential recall. This is unusual as older age has been found to have significant negative impacts on recall in cross-sectional memory studies (Baltes & Kliegl, 1992; Castel, 2005; Castel, 2007; Craik & Jennings, 1992; Lövdén, et al., 2004; Salthouse, 1996; Salthouse, 2009; van Hooren, et al., 2007). Given the substantial floor effect in recall for both types of cue-stem pairs, it is likely that the memory task was difficult for individuals of all ages such that other factors (i.e., WMC) were more likely than age to predict recall. WMC could act as a proxy measure of age in that age typically reduces WMC along with speed of processing (Bopp & Verhaeghen, 2005). In this study, it seems likely that WMC accounted for the variance in recall that was also shared by age, leaving nothing unique left for age to explain. Another likely explanation would be the overwhelming number of younger participants in the study compared to middle-aged and older participants. Nearly half of the sample was under the age of 30 and this likely impacted any effect that age would have had on the statistical analysis.

The facilitative effect that domain knowledge had on recall of realistic cue-stem pairs over fictitious ones in the present study was expected; less expected was the finding that domain knowledge facilitated recall overall. Typically, domain knowledge facilitates the recall of information within the domain of experience and is not facilitative to recall outside of that domain (Halpern & Wai, 2007; Hambrick & Engle, 2002; Jeong & Kim, 2009; Miller, 2003; Tuffiash, Roring, & Ericsson, 2007; Weber & Brewer, 2003). The theory of long-term working memory proposed by Ericsson and Kintsch (1995) indicates that domain experts should only be able to temporarily access long-term memory with the speed and efficiency of working memory when the information being accessed is domain congruent. This theory fits with the present study's findings for differential recall but not for overall recall. A better explanation may come from schema theory (Castel, 2005; Castel, 2007; Hess, 2005; Hess & Slaughter, 1990) wherein greater levels of domain knowledge allow individuals to organize novel information into existing schema more readily. Although the fictitious cue-stem pairs did not fit into the schema of grocery items an individual would likely experience, they could conceivably fit into the over-arching schema of *possible* grocery items. Using this theoretical framework, individuals in the present study with greater amounts of domain knowledge had larger schema for grocery items that enabled them to more readily make meaningful connections among the information already within the schema and all of the presented cue-stem pairs. This effect was pronounced with the realistic cue-stem pairs over the fictitious ones as the realistic pairs fit within the schema more readily and with more and more meaningful connections. Given that domain knowledge facilitated the recall of both types of cue-stem pairs, it is unsurprising that it also facilitated overall recall although this effect was quite weak when compared to other factors such as WMC.

As expected, working memory capacity had a large facilitative effect on overall recall of cue-stem pairs. WMC is an expected contributor to overall recall as it acts as a gateway to longer-term memory (Baddeley, 2010) and has been shown to account for a sizeable portion of variability in long-term recall (Park, et al., 1996). This finding makes sense in light of the fact that it contributed to overall recall, rather than differential recall per se. Individuals with larger WMC were better able to recall the cue-stem pairs regardless of the congruence or incongruence of the information to a particular domain. Although the domain knowledge test was weak, some findings (i.e., large effect in the difference in types of items recalled) suggest that domain knowledge had some effect on recall. WMC seemed to contribute greatly to recall of all types of information, whereas domain knowledge was a significant contributor to recall when information was congruent to that domain. Both domain knowledge and WMC had facilitative effects on recall, which when taken together support a rich-get-richer, or over-additive model.

Using the original method of measuring domain knowledge, the present study did not find support for a moderating effect of domain knowledge on the relationship between age and declarative memory, or on the relationship between WMC and declarative memory. These findings are partially in contrast to Hambrick and Engle's (2002) findings wherein higher levels of domain knowledge facilitated recall at higher levels of WMC, albeit in a different domain. A grocery environment may be a domain in which individuals do not vary greatly in their level of domain knowledge, and a different domain that is salient to older adults could provide more variability such that an over-additive model could emerge. Literature that has explored consumers' knowledge and accuracy of market prices for commonly occurring grocery commodities such as milk, coffee, and cereal have found that most consumers are inaccurate of market price estimation for products (Aalto-Setälä & Jaijas, 2003; Conover, 1986; Urbany & Dickson, 1991). Remarkably, one study found that over 50% of shoppers were unable to recall the price of an item 30 seconds after selecting it and placing it in their cart (Dickson & Sawyer, 1990). Taken together, these results suggest that most consumers do not have a substantial body of knowledge for prices in a grocery shopping domain. One reason for this may be that internal representations of prices are inaccurate due to market fluctuations (Aalto-Setälä & Raijas, 2003)

Exploratory analyses garnered interesting and slightly different results. Items within the domain knowledge measure that did not discriminate high and low scores were removed, thus increasing internal consistency reliability. In addition, this revised measure of domain knowledge was combined with a behavioral measure of domain expertise; that is, frequency of weekly shopping behavior. This combined measure not only acted as a more reliable measure of domain knowledge, but also captured aspects of domain knowledge that were both procedural and declarative. With respect to verbatim recall, this exploratory step found no substantively different results; again, a rich-get-richer model was supported. However, analyses of the gist-based recall revealed a three-way interaction in which domain knowledge moderated the relationship between WMC and differential recall. At lower levels of WMC, higher levels of domain knowledge facilitated more accurate recall for realistic cue-stem pairs, whereas at higher levels of WMC, the impact of domain knowledge on recall of cue-stem pairs was nonexistent. As the market research indicates, most people are unable to recall the exact prices of market items (Aalto-Setälä & Jaijas, 2003; Conover, 1986; Urbany & Dickson, 1991); however, the exploratory results seem to suggest that individuals with lower levels of WMC and higher levels of domain knowledge may bootstrap their knowledge to obtain relatively accurate ballpark figures for prices they have learned. It may be that higher levels of

WMC provide sufficient cognitive resources such that any additional benefits of domain knowledge become unneeded. These results support a compensatory model in which higher levels of domain knowledge moderate the relationship between WMC and gist-based recall of realistic, but not fictitious, cue-stem pairs, and only at lower levels of WMC.

As part of an exploratory step in the present study, cognitive strategy was found to enhance the recall of cue-stem pairs across both types of stimuli. The positive effect that cognitive strategy use has on later recall is well documented throughout the literature, so it was unsurprising to find similar results in the present study (Baltes & Kliegl, 1992; Hill, et al., 1990; Hill, et al., 1993; Kliegl, et al., 1989; Kliegl, et al., 1990; Luo & Craik, 2008). Also, nearly 70% of the participants in the present study used a strategy that was more efficient than repetition, which is a greater proportion than what has been found in one study that explored self-generated strategy use (Hill, Allen, & Gregory, 1990). One might expect that individuals with greater domain knowledge would use this knowledge to generate elaborative strategies that in turn would enhance recall, although there is as yet no research literature that examines this hypothesis and data from the current study were not suitable for conducting this analysis.

Because free-recall tasks require more effort and use more cognitive resources, some researchers posit that older adults are more likely to rely on gist-based recall rather than verbatim recall (Castel, et al., 2007). The present study assessed gist recall in a supplementary analysis. In this analysis, recall was assessed as a distance score, or the absolute distance of the recalled price from the actual price. Neither age nor domain knowledge impacted differential or overall gist recall. However, those individuals with greater WMC had better overall gist recall. Perhaps a more interesting finding was that individuals with greater WMC had better gist recall for realistic cue-stem pairs than for fictitious ones. These findings suggest that basic cognitive ability (e.g., WMC) is an important variable in later recall of every-day quantitative information, but that experience in a domain also plays a role in recall (e.g., realistic items).

A primary purpose in the strengths-based positive psychology research is to find ways in which individuals can use their extant skills or resources to overcome difficulties. For instance, within the literature on memory and aging, some authors suggest learning mnemonic devices that rely on an individual's body of knowledge to enhance recall of common pieces of information such as dates or telephone numbers (Hill, 2005). This approach seems useful in a clinical setting, particularly in light of the findings from the present study; individuals looking to enhance their memory or overcome memory deficits could be taught how to enhance recall using well-developed schema of information, or be taught specific memory strategies (i.e., mnemonics). These suggestions are in line with the body of research that has formally trained aging adults to enhance recall by training them in the use of mnemonic techniques (Hill, et al., 1997; Kliegl, et al., 1987), or instructing them in developing their own cognitive strategies that in some instances may provide for better recall (Baltes, 1998; Derwinger, et al., 2005). It may be that most individuals are not cognizant of the power of cognitive strategies, and that simply being made aware of their utility could provide a powerful tool that is relatively easy for clinicians to develop and administer to clients (Hertzog & Dunlosky, 2008).

Limitations and Future Research

Several limitations must be considered when interpreting the results of this study including sample size, sampling effects, and design limitations. Although the present study had a modest sample of 218 individuals (after screening, 198), post-hoc power analyses showed low power for most of the 2- and 3-way interactions that were the primary foci of this study. Increasing the sample size would directly impact the power of these analyses to detect even weak 2 and 3-way interactions. Additionally, power was low for some of the main effects that were predicted but never appeared (e.g., age). Because they were a readily available and convenient population from which to sample, the Educational Psychology subject pool comprised a bulk of the study sample. These individuals are primarily younger and contributed to a skewed distribution of participants' age that subsequently impacted the effect that age would have had on recall. Therefore, the sampling methodology of this study was a significant limitation. This issue limits the ability to generalize the results of this study to the general population as the sample speaks more to a university population. A larger sample of middle-aged and older adults from the community would likely increase power and improve the statistical analysis for future research.

An additional and important limitation in this study was the low reliability of the domain knowledge measure. Low reliability of this measure makes interpretation of the simple or interactive effects of domain knowledge difficult because of the relationship between reliability and validity; that is, unreliable instruments are inherently invalid and cannot correlate with other measures. Within the present study, although domain knowledge was found to contribute to recall for realistic items it is difficult to know whether domain knowledge was what was actually being measured and in turn impacting recall. At the same time, domain knowledge was weakly related to the recall of realistic cue-stem pairs and not to fictitious cue-stem pairs; domain knowledge was also weakly related to frequency of grocery shopping. Of note, substituting frequency of shopping as a proxy for domain knowledge garnered no significant change in impact of expertise/domain knowledge in the results; indeed, the only significant predictor was WMC. Both of these observations provide a modicum of convergence that strengthens the construct validity of the domain knowledge measure.

The present study, along with marketing research (Aalto-Setälä & Jaijas, 2003; Conover, 1986; Dickson & Sawyer, 1990; Urbany & Dickson, 1991), found that most individuals do not have accurate internal representations of prices. Because of this, future research into domain knowledge for prices in shopping domains may need to focus on developing different methods of assessment of knowledge of prices, such as including nondeclarative (i.e., behavioral) methods. The present study attempted this as an exploratory step, but future studies could be more deliberate about including assessments of procedural domain knowledge, alongside declarative recollections of market prices, as an attempt to gain more reliable data Such approaches could include frequency of shopping (such as in the present study), number of years spent as the primary household shopper, or time spent engaging in activities associated with shopping such as finding coupons, or looking for deals or sales. Given that the declarative and procedural assessments of domain knowledge are correlated, combining them into a composite index would also boost reliability of this measure even if individual subtests are unreliable.

The present study only assessed immediate recall, which ignores how much an individual forgets over time. A more robust approach to studying memory as a construct would be to include a measure of delayed recall, such as at a 7-day posttest as has been done by others (Bermingham, et al., 2010). Although this procedural step introduces the possibilities of practice effects, it could clarify the picture of how strategy use, domain knowledge, WMC, and age impact delayed recall. For instance, Bermingham, et al. (2010) found that the facilitative use of cognitive strategies was moderated by measured numeric ability for recall averaged across a 7-day period and for information forgotten over a 7-day period. Therefore, it seems reasonable to include a delayed recall interval for future research as age, WMC, or domain knowledge could have delayed effects that were not measured in the present study.

Regarding the use of cognitive strategies, the present study was unable to use cognitive strategies as a variable during the statistical analysis because the frequency distributions across types of strategies used was highly variable. A larger sample might overcome this difficulty. Alternatively, many studies have trained individuals in the use of mnemonics as an intervention. Future research could incorporate such an intervention to examine whether instruction in formalized mnemonics improves recall compared to self-generated strategies, or no strategies. This, combined with a delayed recall interval, would replicate the design of many notable memory studies and studies on the use of mnemonics (Hill, et al., 1997; Kliegl, et al., 1990; Kliegl, et al., 1987; Luo & Craik, 2008).

In sum, the present study addressed recommendations to include working memory capacity when examining whether domain knowledge moderates the relationship between aging and memory (Hambrick & Engle, 2002), and to assess recall in a domain salient to older individuals (Hess, 2005). Domain knowledge was not found to moderate the relationship between age or WMC and declarative memory, thereby supporting a building-blocks model. Cognitive resources such as WMC, and factors that influence cognition such as aging, appear fundamental to declarative memory functioning. Compensations for memory impairments are likely to come from other areas, such as using mnemonics or cognitive strategies, rather than from information that one has learned across a lifetime.

APPENDIX A

UNIVERSITY OF UTAH IRB APPROVAL

IRB_00056318

Chair Decision: Approved as submitted

INSTITUTIONAL REVIEW BOARD
THE UNIVERSITY OF UTAH
75 South 2000 East Salt Lake City, UT 84112 | 801.581.3655 | IRB@utah.edu

IRB: IRB_00056318

PI: Douglas Bermingham

Title: The Price is Right: The Impacts of Age, Quantitative Knowledge, Working Memory, and
Cognitive Strategy Use on Memory for Quantitative Information.

Thank you for submitting your request for approval of this study. The IRB has administratively reviewed your application and a designated IRB member has determined that your study is exempt from further IRB review, under 45 CFR 46.101(b), Category 2, from the Federal regulations governing human research.

It is the policy of the University of Utah that all human subject research which is exempt under this section will be conducted in accordance with (1) the Belmont report (http://ohrp.osophs.dhhs.gov/humansubjects/guidance/belmont.htm), (2) this institution's administrative procedures to ensure valid claims of exemption, and (3) orderly accounting for such activities. All research involving human subjects must be approved or exempted by the IRB before the research is conducted (http://www.research.utah.edu/irb/guidelines/pdf/IGS/IGS-ExemptResearch.pdf).

Since this determination is not an approval, it does not expire or need renewal. This determination of exemption from continuing IRB review only applies to the research study as submitted to the IRB and you are expected to follow the protocol as outlined. Before implementing any changes in the study, you must submit an amendment application to the IRB and secure either approval or a determination of exemption.

If you have questions about this, please contact our office at 581-3655 and we will be happy to assist you. Thank you again for submitting your proposal.

Click IRB_00056318 to view the application.

Please take a moment to complete our customer service survey. We appreciate your opinions and feedback.

APPENDIX B

UTAH DEPARTMENT OF HUMAN SERVICES IRB APPROVAL

State of Utah

GARY R. HERBERT
Governor

GREG BELL
Lieutenant Governor

DEPARTMENT OF HUMAN SERVICES

PALMER DePAULIS
Executive Director

MARK L. BRASHER
Deputy Director

MARIE CHRISTMAN
Deputy Director

Date: March 20, 2013

Primary Investigator: Doug Berminham

DHS IRB Number: 0517
Please include this number on all subsequent correspondence

Subject: The Price is Right: The Impacts of Age, Quantitative Knowledge and Cognitive Strategy use on Memory for Quantitative Information
DHS IRB Review finding: Final Approval

Thank you for your submission of Changes to Research Protocol. The Department of Human Services' Institutional Review Board (DHS IRB) has reviewed the modifications and approved the subject protocol.

Expiration date: *March 20, 2014*
You may not conduct any research after this expiration date unless you submit a continuing review resubmission form that is approved by the DHS IRB or one of its representatives. If you suspect that your research will continue beyond the expiration date you must complete the attached ongoing/amendment form along with a status report and resubmit for subsequent review and approval at least one month prior to expiration. If we have not received your resubmission prior to the expiration date, and if the research is ongoing, you will need to resubmit a full protocol application and request IRB approval. Additionally, data collected and/or analyzed during any period of time in which the IRB approval is not in effect, will have to be destroyed or discarded.

Approved documents:

Document Type	Document Name
Research Proposal	Title: The Price is Right: The Impacts of Age, Quantitative Knowledge and Cognitive Strategy use on Memory for Quantitative Information-Version resubmitted 2/252013
Informed Consent/Assent Documents	Version submitted 2/20/2013
Recruitment	Version submitted 2/25/2013
Assessment instruments	Version submitted 2/25/2013

Amendments:
In the event that any further changes are made to the research following this approval (e.g., changes in target population, materials to which subjects are to be exposed, procedures to be employed, etc.), please document these changes in a letter and send it to the DHS IRB.

DHS IRB contact information:
If you need further assistance, please contact Peggy Matlin, IRB Representative, at pmatlin@utah.gov, or Frank Rees, Ph.D., IRB Chair, at frees@utah.gov.

Final Report:
Once your research is completed, please send a copy of your final report to the DHS IRB to allow its members and the Department to benefit from your research findings.

Thank you for your cooperation during this review process and good luck in your endeavors.

Sincerely,

Frank M. Rees, Ph.D.

Frank Rees, Ph.D., Chair
DHS Institutional Review Board

cc Navina Forsythe, Ph.D.
Peggy Matlin
Amy Smith

APPENDIX C

CONSENT DOCUMENT

Consent Document

BACKGROUND
You are being asked to take part in a research study. This study is being conducted as a Doctoral Dissertation research project. Before you decide to participate, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. If there is anything that is not clear, or you would like more information, please ask us.

The purpose of this study is to examine the different ways in which people remember various forms of information. In addition, we are interested in whether people of different age groups remember this information with greater or lesser accuracy.

STUDY PROCEDURE
It will take approximately 1 hour to complete this study. As part of this study, you will be asked to answer questions on a computer. You will be asked to answer questions about yourself, and questions relating to commonly occurring grocery items. Also, you will be asked to memorize information and asked to remember it at a later time.

RISKS
The risks of this study are minimal. You may feel upset or frustrated when answering questions which may prove to be difficult, or when trying to remember information. These risks are similar to those you experience when trying to balance a checkbook, perform a crossword puzzle, or remember a telephone number. If you feel upset from this experience, you can tell the researcher and he will tell you about resources available to help.

BENEFITS
There are no direct benefits for participating in this research. However, we hope the information we get from this study may help develop a greater understanding of how memory across age groups functions.

CONFIDENTIALITY
Your data from this study will be kept confidential. All data records are stored on a password protected web server. Only the researcher and his faculty sponsor will have access to this information. In addition, no identifying information will be collected; therefore, you cannot be identified from your data, and vice versa.

PERSON TO CONTACT
If you have questions, complaints or concerns about this study, you can contact the researcher, Doug Bermingham at 801-671-2687 or via email at doug.bermingham@utah.edu. If you feel you have been harmed as a result of participation, please call Dr. Michael Gardner at 801-581-4475 who you may reach during daytime hours.

Institutional Review Board: Contact the Institutional Review Board (IRB) if you have questions regarding your rights as a research participant. Also, contact the IRB if you have questions, complaints or concerns which you do not feel you can discuss with the investigator. The University of Utah IRB may be reached by phone at (801) 581-3655 or by e-mail at irb@hsc.utah.edu.

Research Participant Advocate: You may also contact the Research Participant Advocate (RPA) by phone at (801) 581-3803 or by email at participant.advocate@hsc.utah.edu.

VOLUNTARY PARTICIPATION

Participation in this research is voluntary. You can refuse to participate, or withdraw from participation at any with without penalty or loss of benefits to which you would otherwise be entitled. This will not affect your relationship with the investigator.

COSTS AND COMPENSATION TO PARTICIPANTS

There are no costs involved in participating in this research.

If you are a member of the subject pool, you will receive academic credit for your educational psychology course. If you do not wish to participate as a research subject, you may complete the research requirement by reading five book chapters on educational research methodology and taking a multiple-choice test on each selection. More details on how to complete your course credit without participating in research have been provided by your course instructor. Choosing not to participate in this research will have no impact on your course grade.

If you are not a member of the subject pool, you will be provided with information about how to improve your memory as compensation for participating in this research. Upon your request, you will be provided with a website link which will provide you with feedback on how you performed on the verbal, mathematical, and memory portions of this research. In addition, you will be provided with individualized information on how to improve your memory based on your performance.

You will also be placed into a raffle for one of four, $50 gift certificates to a Smith’s grocery store or a Smith’s Marketplace. In order to participate in the raffle, you will need to provide contact information so we can contact you when the raffle is over.

CONSENT

By signing this consent form, I confirm I have read the information in this consent form and have had the opportunity to ask questions. I will be given a signed copy of this consent form. I voluntarily agree to take part in this study.

____

Printed Name of Participant

____________________________________ ______________________

Signature of Participant Date

Printed Name of Person Obtaining Consent

Signature of Person Obtaining Consent

Date

APPENDIX D

RECRUITMENT FLYER

Department of Educational Psychology

Memory Study

Participants Needed

We are looking for women without significant memory problems (e.g. Alzheimer's disease) who are interested in participating in a research study on human memory. This study is being conducted to better understand how women's memory typically works across a range of ages.

What to expect from participating:

1) Answering a variety of questions on a computer
2) Memorizing and recall every-day information

Compensation:

1) You will be compensated for your time - contact the researcher for more details.
2) Individual results about your performance on several measures of memory and domain knowledge from the study.

Contact:

If you are interested in participating or want to learn more, please contact Doug Bermingham at 801-671-2687, or at numbermem@gmail.com

Memory Study
Doug Bermingham
801-671-2687
numbermem@gmail.com

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APPENDIX E

RECRUITMENT PRINT ADVERTISEMENT

Memory Study – Participants Needed!!!
University of Utah Doctoral student in Psychology is looking for women without significant memory problems to participate in a psychological study on human memory. Participants will answer questions, and memorize and recall every-day information. Length: about 1 hour. Participants will receive compensation including results on how they performed on the various tasks during the study. If interested please contact Doug Bermingham at 801-671-2687, numbermem@gmail.com.

APPENDIX F

DOMAIN KNOWLEDGE TEST

1. Diced Tomatoes (canned, 14.5 oz)
   a. .21
   b. .67
   c. 1.13
   d. 1.58
   e. 2.04

2. Red Leaf Lettuce (1 head)
   a. 1.09
   b. 1.30
   c. 1.51
   d. 1.73
   e. 1.94

3. Penne Pasta (1 pound box or bag)
   a. 1.22
   b. 1.82
   c. 2.41
   d. 3.00
   e. 3.59

4. Radishes (1 bunch)
   a. .61
   b. .44
   c. .79
   d. .96
   e. 1.13

5. Kidney Beans (canned, 14.5 oz)
   a. .96
   b. 1.22
   c. 1.49
   d. 1.76
   e. 2.03

6. Mayonnaise (1 jar, 15 oz)
   a. 1.06
   b. 2.12
   c. 3.18
   d. 4.24
   e. 5.30

7. 1/2 Gallon of 2% Milk
   a. 1.04
   b. 1.43
   c. 1.82
   d. 2.20
   e. 2.59

8. Cheddar Cheese (8 oz)
   a. 1.44
   b. 2.21
   c. 2.97
   d. 3.73
   e. 4.50

9. 12-Pack of Canned Soda
   a. 3.01
   b. 3.95
   c. 4.89
   d. 5.84
   e. 6.78

10. Maple Flavored Pancake Syrup (24 oz)
    a. 2.34
    b. 3.29
    c. 4.26
    d. 5.23
    e. 6.19

11. Ice Cream (1 pint)
    a. 3.22
    b. 4.21
    c. 5.22
    d. 6.23
    e. 7.23

12. Ground Coffee (11.5 oz tub)
    a. 1.41
    b. 3.61
    c. 5.81
    d. 8.02
    e. 10.22

13. Wheat Thins Crackers (10 oz box)
    - **a. 2.99**
    - b. 3.64
    - c. 4.28
    - d. 4.92
    - e. 5.56

14. Vegetable Oil (48 oz)
    - a. .68
    - b. 1.93
    - c. 3.18
    - **d. 4.42**
    - e. 5.67

15. Ranch Dressing (16 oz)
    - a. .94
    - b. 1.82
    - **c. 2.71**
    - d. 3.59
    - e. 4.47

16. Macaroni and Cheese (7.25 oz box)
    - a. .05
    - b. .53
    - c. 1.01
    - d. 1.49
    - **e. 1.97**

17. Grape Juice (64 oz bottle)
    - **a. 2.53**
    - b. 3.57
    - c. 4.61
    - d. 5.66
    - e. 6.70

18. Greek Yogurt (6 oz)
    - a. .61
    - b. .94
    - **c. 1.27**
    - d. 1.60
    - e. 1.93

19. Margarine (16 oz tub)
    - a. 1.65
    - **b. 2.54**
    - c. 3.42
    - d. 4.30
    - e. 5.19

20. Cucumber (A single one)
    - a. .24
    - b. .36
    - c. .48
    - **d. .60**
    - e. .72

21. Triscuit Crackers (9 oz box)
    - a. 2.35
    - **b. 2.99**
    - c. 3.64
    - d. 4.28
    - e. 4.92

22. Pringles Potato Chips (1 tube)
    - a. 1.00
    - b. 1.19
    - c. 1.38
    - d. 1.58
    - **e. 1.77**

23. Sugar (White, 5-pound bag)
    - a. 2.49
    - **b. 2.92**
    - c. 3.35
    - d. 3.78
    - e. 4.21

24. Sour Cream (16 oz container)
    - a. .72
    - b. 1.11
    - c. 1.49
    - **d. 1.88**
    - e. 2.26

25. Packaged Instant Oatmeal (11.8oz box)
    a. .74
    b. 1.82
    c. 2.91
    d. 3.99
    e. 5.07

26. Medium Flour Tortillas (Package of 8)
    a. .44
    b. 1.11
    c. 1.77
    d. 2.44
    e. 3.10

27. Peanut Butter (16 oz jar)
    a. 2.06
    b. 2.72
    c. 3.38
    d. 4.04
    e. 4.71

28. Parsley, 1 bunch
    a. .55
    b. .68
    c. .81
    d. .94
    e. 1.07

29. Ground Beef (1 pound, 80% lean)
    a. 1.30
    b. 2.35
    c. 3.40
    d. 4.45
    e. 5.49

30. Gallon of Milk (Skim)
    a. 3.11
    b. 3.88
    c. 4.65
    d. 5.42
    e. 6.19

APPENDIX G

WORKING MEMORY CAPACITY TESTS

Digit Span Backwards
Instructions

Sample Items
Trial 1

“Now you are going to see some numbers. When the numbers stop, please type them in backwards. For instance, if you saw: 6 - 2, what you would you type?”

Correct Response: “That's right! (proceed to Trial 2)”

Incorrect Response: “That's not quite right. The numbers you saw were 6 - 2, so backwards they would be 2 - 6.” (Proceed to trial 2)

Trial 2

“Let's try another one. Remember to say them backwards. 4 – 5”

Correct Response: “That's right!” (proceed to Trial 1 of Item 1)

Incorrect Response: “That's not quite right. The numbers you saw were 5 - 4, so backwards they would be 4 - 5. Let's try some more” (proceed to Trial 1 of item 1)

Item	Trial	Correct Response
1.	3-7	7-3
	4-1	1-4
2.	5-7	7-5
	8-6	6-8
3.	2-3-7	7-3-2
	5-8-4	4-8-5
4.	6-3-8-1	1-8-3-6
	7-1-8-4	4-8-1-7
5.	5-3-4-1-8	8-1-4-3-5
	2-4-5-9-6	6-9-5-4-2
6.	9-5-1-8-6-2	2-6-8-1-5-9
	1-4-2-8-3-7	7-3-8-2-4-1
7.	2-9-8-3-7-4-1	1-4-7-3-8-9-2
	4-5-6-1-7-8-9	9-8-7-1-6-5-4
8.	7-9-8-4-1-3-5-6	6-5-3-1-4-8-9-7
	2-8-1-5-2-9-7-3	3-7-9-2-5-1-8-2

Digit Span Sequencing
Instructions

Sample Items
Trial 1

"Now you are going to see some numbers. When the numbers stop, please type them in, in order, starting with the lowest number. For instance, if you saw: 3-4-2, what you would you type?"

Correct Response: "That's right!" (proceed to Trial 2)

Incorrect Response: "That's not quite right. The numbers you saw were 3-4-2, so in order they would be 2-3-4." (Proceed to trial 2)

Trial 2

"Let's try another one. 6-3-3"

Correct Response: "That's right!" (proceed to Trial 1 of Item 1)

Incorrect Response: "That's not quite right. The numbers you saw were 6-3-3, so in order from lowest to highest you would type 3-3-6. Let's try some more" (proceed to Trial 1 of item 1)

Item	Trial	Correct Response
1.	4-5	4-5
	8-7	7-8
2.	4-1-7	1-4-7
	4-5-2	2-4-5
3.	6-5-1-2	1-2-5-6
	1-8-9-7	1-7-8-9
4.	6-9-1-4-5	1-4-5-6-9
	5-2-5-3-6	2-3-5-5-6
5.	6-3-6-7-9-1	1-3-6-6-7-9
	9-1-2-9-1-4	1-1-2-4-9-9
6.	5-9-1-2-5-3-8	1-2-3-5-5-8-9
	6-6-9-3-4-1-9	1-3-4-6-6-9-9
7.	4-6-1-9-5-7-6-7	1-4-5-6-6-7-7-9
	3-9-4-4-5-8-2-5	2-3-4-4-5-5-8-9
8.	7-1-4-8-5-6-6-4-3	1-3-4-4-5-6-6-7-8
	4-6-4-2-3-1-4-2-9	1-2-2-3-4-4-4-6-9

Letter-Number Sequencing
Instructions

Demonstration Item A

"You will see some numbers and letters. After you see them, I want you to type the numbers first, then the letters. For example, if you saw C-1, you would type 1-C. The number goes first, then the letter."

Sample Item A

"Let's practice. A-4"

Correct Response: "That's right!" (Proceed to Trial 1 of Item 1)

Incorrect Response: "That's not quite right. You saw A-4, so you would type 4-A. The number goes first, then the letter" (Proceed to Trial 1of Item 1.)

Items 1 & 2: Administer all three trials of each item. Proceed to Demonstration Item B if the discontinue criterion has not been met after administration of Item 2 - Discontinue after scores of 0 on **all 3 trials** of an item

Item	Trial	Correct Response
1.	4-D	4-3
	F-3	3-F
	6-F	6-F
2.	G-7	7-G
	5-C	5-C
	E-3	3-E

Demonstration Item B

"Now let's try some with *more* numbers and letters. I want you to type the numbers first, in order, starting with the lowest number. Then tell the letters in alphabetical order."

"For example, if you saw 4-D-3, you would type 3-4-D. You type the numbers first, in order, starting with the lowest number. Then say the letters in alphabetical order. (Proceed to sample item B)"

Sample item B
Trial 1

"Let's practice. F-7-B"

Correct Response: "That's Right! (Proceed to Trial 2)"

Incorrect Response: "That's not quite right. You saw F-7-B. You should type 7-B-F. You say the numbers first, in order, starting with the lowest number. Then say the letters in alphabetical order. (Proceed to Trial 2)"

Trial 2

"Let's try another one. 5-D-6"

Correct Response: "That's right! (Proceed to Trial 1 of item 3)"

Incorrect Response: "That's not quite right. You saw 5-D-6. You should type 5-6-D. You type the numbers first, in order, starting with the lowest number. Then type the letters in alphabetical order. (Proceed to Trial 1 of Item 3)"

Instructions for items 3-10

"Let's try some more. Remember to type the numbers first, in order, starting with the lowest number. Then type the letters in alphabetical order."

Item	Trial	Correct Response
3.	7-E-C	7-C-E
	H-G-3	3-G-H
	5-4-B	4-5-B
4.	3-I-9	3-9-I
	J-2-6	2-6-J
	5-S-9	5-9-S
5.	B-1-P	1-B-P
	O-8-W	8-O-W
	R-5-O	5-O-R
6.	X-3-L-7	3-7-L-X
	9-Z-6-I	6-9-I-Z
	U-2-V-8	2-8-U-V
7.	1-G-8-H-3	1-3-8-G-H
	M-6-E-4-U	4-6-E-M-U
	7-S-5-J-8	5-7-8-J-S
8.	O-6-R-9-T-4	4-6-9-O-R-T
	8-P-2-L-5-U	2-5-8-L-P-U
	W-8-J-7-H-5	5-7-8-J-H-W
9.	T-9-X-6-A-1-H	1-6-9-A-H-T-X
	2-Z-4-L-5-P-9	2-4-5-9-L-P-Z
	O-3-S-1-T-6-F	1-3-6-F-O-S-T
10.	8-R-9-U-4-P-2-C	2-4-8-9-C-P-R-U
	W-3-T-2-Z-6-M-5	2-3-5-6-M-T-W-Z
	9-O-4-V-8-H-2-C	2-4-8-9-C-H-O-V

APPENDIX H

DECLARATIVE MEMORY TEST

Fictitious Items

1. Knoode (8 oz)	$1.66
2. Thorge	$ .82
3. Loaf of Rhoond	$4.67
4. Dried Phoap (8 oz)	$3.10
5. Bourf	$2.22
6. Shoapes	$2.86
7. Pickled Fribbs (16 oz jar)	$3.90
8. Shround	$2.78
9. Roasted Chuff (8 oz)	$1.25
10. Fresh Dorpes (1 bunch)	$1.49
11. Frozen Yont (16 oz)	$3.34
12. Shrump (1 lb)	$5.11
13. Trairs	$ .67
14. Twoosh (1 Gallon)	$1.23
15. Canned Volms (5 oz)	$1.91

Realistic Items

1. Frozen Corn (16 oz)	$1.71
2. Tortilla Chips (11 oz)	$2.48
3. Chicken Stuffing (box)	$1.69
4. Loaf of Wheat Bread	$2.83
5. Strawberry Jam (32 oz jar)	$3.52
6. Pudding Snacks (4 pack)	$1.30
7. Dozen Eggs	$2.30
8. Microwavable Popcorn (3 bags)	$2.90
9. Hot Dogs (16 oz package)	$4.12
10. Canned Chunk Albacore Tuna	$1.53
11. Sugar (5 lbs)	$2.92
12. Iceberg Lettuce (1 head)	$ .99
13. Dill Pickle Spears (24 oz jar)	$2.76
14. Cream Cheese (8 oz)	$2.48
15. Brownie Mix (box)	$2.45

APPENDIX I

DEMOGRAPHICS QUESTIONNAIRE

Demographics

Please answer the following questions by either selecting the best answer by clicking the selection, or filling in the blank. <u>If you do not know the answer, or do not wish to answer, please leave the question blank. If you do not know the exact answer, please give your best guess.</u>

You will have 5 minutes to complete the form, after which time the computer will automatically take you to the next page. <u>If you do not complete the form before the computer takes you to the next page, please let the researcher know.</u>
Age:

Ethnicity:

White (Non-Hispanic)	Asian	African American or Black
Hispanic or Latino	Native American	Pacific Islander

Other:

Education Information
If you are a student, your major:__________
If already graduated, the area of your degree:__________
Number of Years of Education (e.g., High School Graduate = 12 years:_____
Highest Level of Education Achieved:_____
Number of Courses Taken In Mathematics (Including High School):_____

Grocery Shopping Information
Are you the person who does most of the grocery shopping for your household?
Yes No

Approximately how many times a week would you say you go grocery shopping for your household?
I do not do the grocery shopping
1 or less times per week
2-3 times per week
Nearly Every day

How many people do you shop for in your household?
Myself
2 people
3 people
4 people
5 people
6 or more people

<u>**Further Directions**</u>
If you have finished filling out the above demographics information, please read the following paragraphs until the computer automatically takes you to the

next page. Please pay attention, as you will be asked to recall some of this information later.

The five baboon species are some of the largest non-hominid members of the primate order; only the Mandrill and the Drill are larger. In modern scientific use, only members of the genus Papio are called baboons, but previously the closely related Gelada (genus Theropithecus) and two species of Mandrill and Drill (genus Mandrillus) were grouped in the same genus, and these Old World monkeys are still often referred to as baboons in everyday speech. The word "baboon" comes from "babouin", the name given to them by the French naturalist Buffon. The baboon held several positions in Egyptian mythology. The baboon god Baba, was worshipped in Pre-Dynastic times; alternatively, this may be the origin of the animal's name. Papio belongs to family Cercopithecidae, in subfamily.

All baboons have long dog-like muzzles (cynocephalus, "dog-head"), close-set eyes, heavy powerful jaws, thick fur except on their muzzle, a short tail and rough spots on their protruding hindquarters, called ischial callosities. These callouses are nerveless, hairless pads of skin which are present to provide for the sitting comfort of the baboon (and other Old World monkeys). Males of the Hamadryas Baboon species also have a large white mane.There is considerable variation in size and weight depending on species, the Guinea Baboon is 50 cm (20 inches) and weighs only 14 kg (30 lb) while the biggest Chacma Baboon can be 120 cm (47 inches) and weigh 40 kg (90 lb). In all baboon species there is pronounced sexual dimorphism, usually in size but also sometimes in colour or canine development. Baboons are terrestrial (ground dwelling) and are found in open savannah, open woodland and hills across Africa. Their diet is omnivorous, but is usually vegetarian. They are foragers and are active at irregular times throughout the day and night. They can raid human dwellings and in South Africa they have been known to prey on sheep and goats. Their principal predators are man and the leopard, although they are tough prey for a leopard and large males will often confront them by flashing their eyelids, showing their teeth by yawning, making gestures, and chasing after the intruder/predator. Baboons in captivity have been known to live up to 45 years, while in the wild their life expectancy is about 30 years.

Most baboons live in hierarchical troops. Group sizes vary between 5 to 250 animals (often about 50 or so), depending on specific circumstances, especially species and time of year. The structure within the troop varies considerably between Hamadryas Baboons and the remaining species, sometimes collectively referred to as savanna baboons. The Hamadryas Baboon has very large groups comprised of many smaller harems (one male with four or so females), to which females from elsewhere in the troop are recruited while still too young to breed. The other baboon species have a more promiscuous structure with a strict dominance hierarchy based on the female matriline. The Hamadryas Baboon group will typically include a younger male, but he will not attempt to mate with the females unless the older male is removed.Another baboon society in Africa interacts with the Masai by stealing their goats for meat and waiting for Masai to dig in the dry river beds for water. After the Masai leave the water hole, the baboons sneak in to drink whatever water is left. Baboons can determine from vocal exchanges what the dominance relations are between individuals. When a confrontation occurs between different families or where a lower-ranking baboon takes the offensive, baboons show more interest in the exchange than exchanges between members of the same family or when a higher-ranking baboon takes the offensive. This is because confrontations between different families or rank challenges can have a wider impact on the whole troop than an internal conflict in a family or a baboon reinforcing its dominance. The collective noun for baboons is commonly troop or congress, although flange is also becoming common. This unusual term originates from a Not the Nine O'Clock News comedy sketch entitled "Gerald The Intelligent Gorilla" where it was used for comic effect.

The word orangutan (also written orang-utan, orang utan and orangutang) is derived from the Malay and Indonesian words orang meaning "person" and hutan meaning "forest", thus "person of the forest". Orang Hutan is the common term in these two national languages, although local peoples may also refer to them by local languages. Maias and mawas are also used in Malay, but it is unclear if those words refer only to orangutans, or to all apes in general.

The word was first attested in English in 1691 in the form orang-outang, and variants with -ng instead of -n as in the Malay original are found in many languages. This spelling (and pronunciation) has remained in use in English up to the present, but has come to be regarded as incorrect by some.

The name of the genus, Pongo, comes from a 16th century account by Andrew Battell, an English sailor held prisoner by the Portuguese in Angola, which describes two anthropoid "monsters" named Pongo and Engeco. It is now believed that he was describing gorillas, but in the late 18th century it was believed that all great apes were orangutans; hence Lacépède's use of Pongo for the genus.

Orangutans are the most arboreal of the great apes, spending nearly all of their time in the trees. Every night they fashion nests, in which they sleep, from branches and foliage. They are more solitary than the other apes, with males and females generally coming together only to mate. Mothers stay with their babies until the offspring reach an age of six or seven years. There is significant sexual dimorphism between females and males: females can grow to around 4 ft 2 in or 127 centimetres and weigh around 100 lbs or 45 kg, while flanged adult males can reach 5 ft 9 in or 175 centimetres in height and weigh over 260 lbs or 118 kg.

The arms of an orangutan are twice as long as their legs. Much of the arm's length has to do with the length of the radius and the ulna rather than the humerus. Their fingers and toes are curved, allowing them to better grip onto branches. Orangutans have less restriction in the movements of their legs unlike humans and other primates, due to the lack of a hip joint ligament which keeps the femur held into the pelvis. Unlike gorillas and chimpanzees, orangutans are not true knuckle-walkers, and walk on the ground by shuffling on their palms with their fingers curved inwards.

Adult male orangutans exhibit two modes of physical development, flanged and unflanged. Flanged adult males have a variety of secondary sexual characteristics, including cheek pads (called "flanges"), throat pouch, and long fur, that are absent from both adult females and from unflanged males. Flanged males establish and protect territories that do not overlap with other flanged males' territories. Adult females, juveniles, and unflanged males do not have established territories. A flanged male's mating strategy involves establishing and protecting a territory, advertising his presence, and waiting for receptive females to find him. Unflanged males are also able to reproduce; their mating strategy involving finding females in estrus and forcing copulation. Males appear to remain in the unflanged state until they are able to establish and defend a territory, at which point they can make the transition from unflanged to flanged within a few months. The two reproductive strategies, referred to as "call-and-wait" for flanged male and "sneak-and-rape" for the unflanged male, were found to be approximately equally effective in one study group in Sumatra, though this observation did occur during a period of instability in flanged male rank and unflanged male mating success may be lower in Borneo.

Fruit makes up 65% of the orangutan diet. Fruits with sugary or fatty pulp are favored. The fruit of fig trees are also commonly eaten since it is easy to both harvest and digest. Other food items include: young leaves, shoots, seeds and bark. Insects and bird eggs are also included.

Orangutans are thought to be the sole fruit disperser for some plant species including the climber species Strychnos ignatii which contains the toxic alkaloid strychnine. It does not appear to have any effect on orangutans except for excessive saliva production.

Orangutans use plants of the genus Commelina as an anti-inflammatory balm.

Like the other great apes, orangutans are remarkably intelligent. Although tool use among chimpanzees was documented by Jane Goodall in the 1960s, it was not until the mid-1990s that one population of orangutans was found to use feeding tools regularly. A 2003 paper in the journal Science described the evidence for distinct orangutan cultures.

According to recent research by the psychologist Robert Deaner and his colleagues, orangutans are the world's most intelligent animal other than humans, with higher learning and problem solving ability than chimpanzees, which were previously considered to have greater abilities. A study of orangutans by Carel van Schaik, a Dutch primatologist at Duke University, found them capable of tasks well beyond chimpanzees' abilities — such as using leaves to make rain hats and leakproof roofs over their sleeping nests. He also found that, in some food-rich areas, the creatures had developed a complex culture in which adults would teach youngsters how to make tools and find food.

A two year study of orangutan symbolic capability was conducted from 1973-1975 by Gary L. Shapiro with Aazk, a juvenile female orangutan at the Fresno City Zoo (now Chaffee Zoo) in Fresno, California. The study employed the techniques of David Premack who used plastic tokens to teach the chimpanzee, Sarah, linguistic skills. Shapiro continued to examine the linguistic and learning abilities of ex-captive orangutans in Tanjung Puting National Park, in Indonesian Borneo, between 1978 and 1980. During that time, Shapiro instructed ex-captive orangutans in the acquisition and use of signs following the techniques of R. Allen and Beatrix Gardner who taught the chimpanzee, Washoe, in the late-1960s. In the only signing study ever conducted in a great ape's natural environment, Shapiro home-reared Princess, a juvenile female who learned nearly 40 signs (according to the criteria of sign acquisition used by Francine Patterson with Koko, the gorilla) and trained Rinnie, a free-ranging adult female orangutan who learned nearly 30 signs over a two year period. For his dissertation study, Shapiro examined the factors influencing sign learning by four juvenile orangutans over a 15-month period.

The first orangutan language study program, directed by Dr. Francine Neago, was listed by Encyclopedia Britannica in 1988. The Orangutan language project at the

Smithsonian National Zoo in Washington, D.C., uses a computer system originally developed at UCLA by Neago in conjunction with IBM.

Zoo Atlanta has a touch screen computer where their two Sumatran Orangutans play games. Scientists hope that the data they collect from this will help researchers learn about socializing patterns, such as whether they mimic others or learn behavior from trial and error, and hope the data can point to new conservation strategies.

Although orangutans are generally passive, aggression toward other orangutans is very common; they are solitary animals and can be fiercely territorial. Immature males will try to mate with any female, and may succeed in forcibly copulating with her if she is also immature and not strong enough to fend him off. Mature females easily fend off their immature suitors, preferring to mate with a mature male.

Orangutans have even shown laughter-like vocalizations in response to physical contact, such as wrestling, play chasing, or tickling.

The name Bonobo first appeared in 1954, when Edward Tratz and Heinz Heck proposed it as a new and separate generic term for pygmy chimpanzees. The term has been reported variously as being a word for "chimpanzee" or "ancestor" in a Bantu language. Another suggestion for the derivation of the name is that the name is a misspelling of the name of the town of Bolobo on the Congo River, which has been associated with the collection of chimps in the 1920s.

The scientific name for the Bonobo is Pan paniscus. Initial genetic studies have characterised their DNA as more than 98% identical to that of Homo sapiens. More recent studies have shown that chimpanzees are more closely related to humans than to the gorillas. The most recent genetic analyses of chimpanzee and human genetic similarity come from whole genome comparisons and have shown that the differences between the two species are more complex, both in extent and character, than the historical 98% figure suggests.

In the seminal Nature paper reporting on initial genome comparisons, researchers identified thirty-five million single-nucleotide changes, five million insertion or deletion events, and a number of chromosomal rearrangements which constituted the genetic differences between chimpanzees and humans, covering ~5% of both genomes. While many of these analyses have been performed on the Common Chimpanzee rather than the Bonobo, the differences between the two chimpanzee species are unlikely to be substantial enough to affect the Pan-Homo comparative data significantly.

There still is controversy, however. Scientists such as Morris Goodman of Wayne State University in Detroit argue that the Bonobo and Common Chimpanzee are so closely related to humans, that their genus name also should be classified with the human genus Homo: Homo paniscus, Homo sylvestris, or Homo arboreus. An alternative philosophy suggests that the term Homo sapiens is the misnomer rather, and that humans should be reclassified as Pan sapiens. In either case, a name change of the genus would be problematic because it would complicate the taxonomy of other species closely related to humans, including Australopithecus.

Recent DNA evidence suggests the Bonobo and Common Chimpanzee species effectively separated from each other less than one million years ago. The chimpanzee line split from the last common ancestor shared with humans approximately four to six million years ago. Because no species other than Homo sapiens has survived from the human line of that branching, both Pan species are the closest living relatives of humans and cladistically are equally close to humans.

The Bonobo is more gracile (slight in form) than the Common Chimpanzee and females are somewhat smaller than males. Its head is smaller than that of the Common Chimpanzee with less prominent brow ridges above the eyes. It has a black face with pink lips, small ears, wide nostrils, and long hair on its head that forms a part. Females have slightly more prominent breasts, in contrast to the flat breasts of other female apes, although not so prominent as those of humans. The Bonobo also has a slim upper body, narrow shoulders, thin neck, and long legs when compared to the Common Chimpanzee. The Bonobo walks upright approximately 25% of the time during ground locomotion. Its quadrupedal ground locomotion generally is characterized by forelimb 'palm walking', similar to orangutans and in contrast to the predominant use of knuckles as characteristic of gorillas and the Common Chimpanzees. These physical characteristics and its posture, give the Bonobo an appearance more closely resembling humans than that of the Common Chimpanzee. The Bonobo also has highly-individuated facial features, as humans do, so that one individual may look significantly different from another, a characteristic adapted for visual facial recognition in social interaction.

Frans de Waal, one of the world's leading primatologists, states that the Bonobo often is capable of altruism, compassion, empathy, kindness, patience, and sensitivity.

Recent observations in the wild indicate that the males among the related Common Chimpanzee communities are extraordinarily hostile to males from outside of the community. Parties of males 'patrol' for the unfortunate neighbouring males who might be traveling alone, and attack those single males, often killing them. (Some researchers have suggested, however, that this behaviour has been caused by a combination of human contact and interference and massive environmental stress caused by deforestation and a corresponding home range reduction.) This does not appear to be the behavior of the Bonobo males or females, both of whom seem to prefer sexual contact over violent confrontation with outsiders. The Bonobo live in different areas from the more aggressive Common Chimpanzee. Neither of the species swims, and they sometimes inhabit ranges on opposite sides of the great Congo River. It has been hypothesized that Bonobos are able to live a more peaceful lifestyle in part, because of an abundance of nutritious vegetation in their natural habitat, allowing them to travel and forage in large parties.

The popular image of the Bonobo as a "peaceful ape" has come under fire by observations of artificially-confined populations. Accounts exist of Bonobos confined in zoos mutilating one another and engaging in bullying. These incidents may be due to the practice in zoos of separating mothers and sons, which is contrary to their social organization in the wild. Bonobo society is dominated by females, and severing the lifelong alliance between mothers and their male offspring may make them vulnerable to female aggression. De Waal has warned of the danger of romanticizing Bonobos: "All animals are competitive by nature and cooperative only under specific circumstances" as well as writing that "When first writing about their behavior, I spoke of 'sex for peace' precisely because bonobos had plenty of conflicts. There would obviously be no need for peacemaking if they lived in perfect harmony". In marked contrast to the Common Chimpanzee there are no confirmed reports of lethal aggression between Bonobos, either in the wild or in captivity. The immature state of Bonobo research in the wild, compared to that of the Common Chimpanzee, however, means that lethal aggression between Bonobos could be discovered.

Hohmann and Surbeck published in 2008 that Bonobos sometimes do hunt monkey species. Having observed a group of bonobos in Salonga National Park for five years they witnessed five incidents where Bonobos preyed on groups of monkeys. Their research indicates it was deliberate hunting, where a group of Bonobos would coordinate their actions—contrary to their normal hunting behaviour, which is quite solitary and less purposeful. In three occasions the hunt was successful and infant monkeys were captured, once a redtail monkey and twice a Cercopithecus wolfi. The spoils, however, were distributed quite peacefully among the members of the group.

Females are considered to have a higher social status in their matriarchal culture. Strong female bonding allows groups of female Bonobos to dominate the community. Aggressive encounters between males and females are rare, and males are tolerant of infants and juveniles. A male's status is derived from the status of his mother. The mother-son bond often stays strong and continues throughout life. While social hierarchies do exist, rank does not play so prominent a role as it does in other primate societies. Bonobo fishing for termites

Bonobo party size tends to be variable since the groups exhibit a fission-fusion pattern. A tribe of approximately one hundred will split into small groups during the day while looking for food, and then come back together to sleep. They sleep in trees on nests they construct. Unlike Common Chimpanzees, who are known to hunt monkeys, Bonobos primarily are frugivores, although they do eat insects and occasionally have been observed catching small mammals such as squirrels and duikers.

Sexual intercourse plays a major role in Bonobo society, being used as a greeting, a means of conflict resolution, and post-conflict reconciliation. With the exception of a pair of Congoese gorillas observed doing so, Bonobos were thought to be the only non-human apes to have been observed engaging in all of the following sexual activities: face-to-face genital sex, tongue kissing, and oral sex. In scientific literature, the female-female sexual behavior often is referred to as GG rubbing or genital-genital rubbing.

Sexual activity happens within the immediate family as well as outside it, and often involves adults and children, including infants. Bonobos never form permanent relationships with individual partners. They also do not seem to discriminate in their sexual behavior by gender or age, with the possible exception of abstaining from sexual intercourse between mothers and their adult sons; some observers believe these pairings are taboo. When Bonobos come upon a new food source or feeding ground, the increased excitement will usually lead to communal sexual activity, presumably decreasing tension and allowing for peaceful feeding.

Bonobo males frequently engage in various forms of male-male genital sexual behavior (frot). In one form, two males hang from a tree limb face-to-face while "penis fencing". Frot also may occur when two males rub their penises together while in face to face position. A special form of frot called "rump rubbing" occurs to express reconciliation between two males after a conflict, when they stand back-to-back and rub their scrotal sacs together.

Bonobo females also engage in female-female genital sexual behavior, (tribadism), to bond socially with each other, thus forming a female nucleus of Bonobo society. The bonding among females allows them to dominate Bonobo society - although male Bonobos are individually stronger, they cannot stand alone against a united group of females. Adolescent females often leave their native community to join another community. Sexual bonding with other females establishes the new females as members of the group. This migration mixes the Bonobo gene pools, providing genetic diversity.

Bonobo reproductive rates are not any higher than that of the Common Chimpanzee. Female Bonobos carry and nurse their young for five years and can give birth every five to six years. Compared to Common Chimpanzees, Bonobo females resume the genital swelling cycle much sooner after giving birth, allowing them to rejoin the sexual activities of their society. Also, Bonobo females who are sterile or too young to reproduce still engage in sexual activity.

Craig Stanford, an American primatologist, has challenged the claim that Bonobos are more sexually active than Common Chimpanzees. Stanford compared existing data on Common Chimpanzees and Bonobos in the natural habitat and found that female Common Chimpanzees copulated at least as often as female Bonobos, while he recorded that male chimpanzees copulated more than male Bonobos. His comparison excluded same-sex sexual contacts, however, which are very common in Bonobos. De Waal's book on Bonobos includes interviews with field workers and relies on the studies by Takayoshi Kano, the only scientist to have worked for two decades with wild Bonobos. New studies in Africa by Gottfried Hohmann, a research associate at the Max Planck Institute for Evolutionary Anthropology of Leipzig, Germany, relate significant violence, but the fact remains that there are thus far no documented cases of lethal aggression among Bonobos, in sharp contrast to the evidence for Common Chimpanzees.

Bonobos are capable of passing the mirror-recognition test for self-awareness. They communicate primarily through vocal means, although the meanings of their vocalizations are not currently known. However, most humans do understand their facial expressions and some of their natural hand gestures, such as their invitation to play. Two Bonobos at the Great Ape Trust, Kanzi and Panbanisha, have been taught how to communicate using a keyboard labeled with lexigrams (geometric symbols) and they can respond to spoken sentences. Kanzi's vocabulary consists of more than 500 English words and he has comprehension of around 3,000 spoken English words. Some, such as philosopher and bioethicist Peter Singer, argue that these results qualify them for the "rights to survival and life," rights that humans theoretically accord to all persons.

There are instances in which non-human primates have been reported to have expressed joy. One study analyzed and recorded sounds made by human babies and Bonobos when they were tickled. It found although the Bonobo's laugh was a higher frequency, the laugh followed a similar spectrographic pattern to human babies.

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